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Rock Creek Fish and Habitat Assessment
for
Prioritization of Restoration and Protection Actions

June 1, 2008 – May 31, 2013

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Contents

Executive Summary

The overall goal of this project is to improve habitat conditions for steelhead trout (*Oncorhynchus mykiss*), listed under the Endangered Species Act (ESA), in the Rock Creek subbasin in southeastern Washington in order to support sustainable populations. This report describes results of the monitoring and evaluation activities, Ecosystem Diagnosis and Treatment (EDT) modeling, and genetic analysis of salmonid populations and habitat conditions in Rock Creek. The project also addresses information gaps identified in the National Oceanographic and Atmospheric Administration (NOAA)-Fisheries' *Recovery Plan for the Rock Creek Population of Middle Columbia River Steelhead* and the Northwest Power & Conservation Council's (NPCC) *Rock Creek Subbasin Plan*, which state that ongoing monitoring and evaluation within the Rock Creek watershed is a high priority.

The Rock Creek subbasin is of great significance to the Yakama Nation, and to the Rock Creek Band in particular. Oral history describing historic runs of anadromous and resident fish and perennial flows in the subbasin indicate that fish populations and habitat have been significantly altered from historic conditions. The subbasin has been identified as a potentially productive watershed for steelhead, but with significant habitat limitations (low flow, high stream temperatures, and riparian, channel and floodplain degradation).

This report summarizes progress and results for the following major objectives under this contract:

1. Monitoring and Evaluation-- to assess current habitat conditions, limiting factors and status of salmonid populations in the subbasin, including: juvenile fish abundance, distribution, movement, habitat use, life history, growth, survival to adulthood and adult distribution, relative abundance, and spawning behavior (e.g. kelting). (Section 1, Reports A & B).
2. Ecosystem Diagnosis and Treatment (EDT) modeling-- to evaluate habitat quality and identify areas with potential for habitat restoration, and implications of habitat restoration in the subbasin. (Section 2, Report C).
3. Genetics-- to determine the genetic composition of resident (rainbow) trout and steelhead (*O. mykiss*) populations, and to compare genetic samples for heterogeneity within the subbasin. (Section 3, Report D).
4. Revegetation-- Riparian revegetation along stream corridor to increase stream shading and lower stream temperatures at several sites. (Section 4).

A literature survey compiled through a separately funded geomorphic analysis details previous work that has been conducted in Rock Creek, and is presented in Appendix B.

The Rock Creek subbasin encompasses an area of approximately 223 square miles of southeastern Washington. Rock Creek flows south to the Columbia River at river mile (RM) 230, approximately 12 miles upstream of John Day Dam (Figure 1). The lowermost portion (1.2 mi.) is inundated by the backwaters of the John Day Dam. Elevations range from 200 feet at the confluence to over 3,200 feet in the Simcoe Mountains. Annual precipitation ranges from approximately 8 inches at the confluence to 24 inches in the headwaters. From June through September, the stream flow in Rock Creek and its tributary streams decreases, becoming intermittent until the fall rains resume (generally in October or November). Major tributaries to Rock Creek include Squaw Creek, Quartz Creek, Badger Creek, Luna Creek, and Harrison Creek.

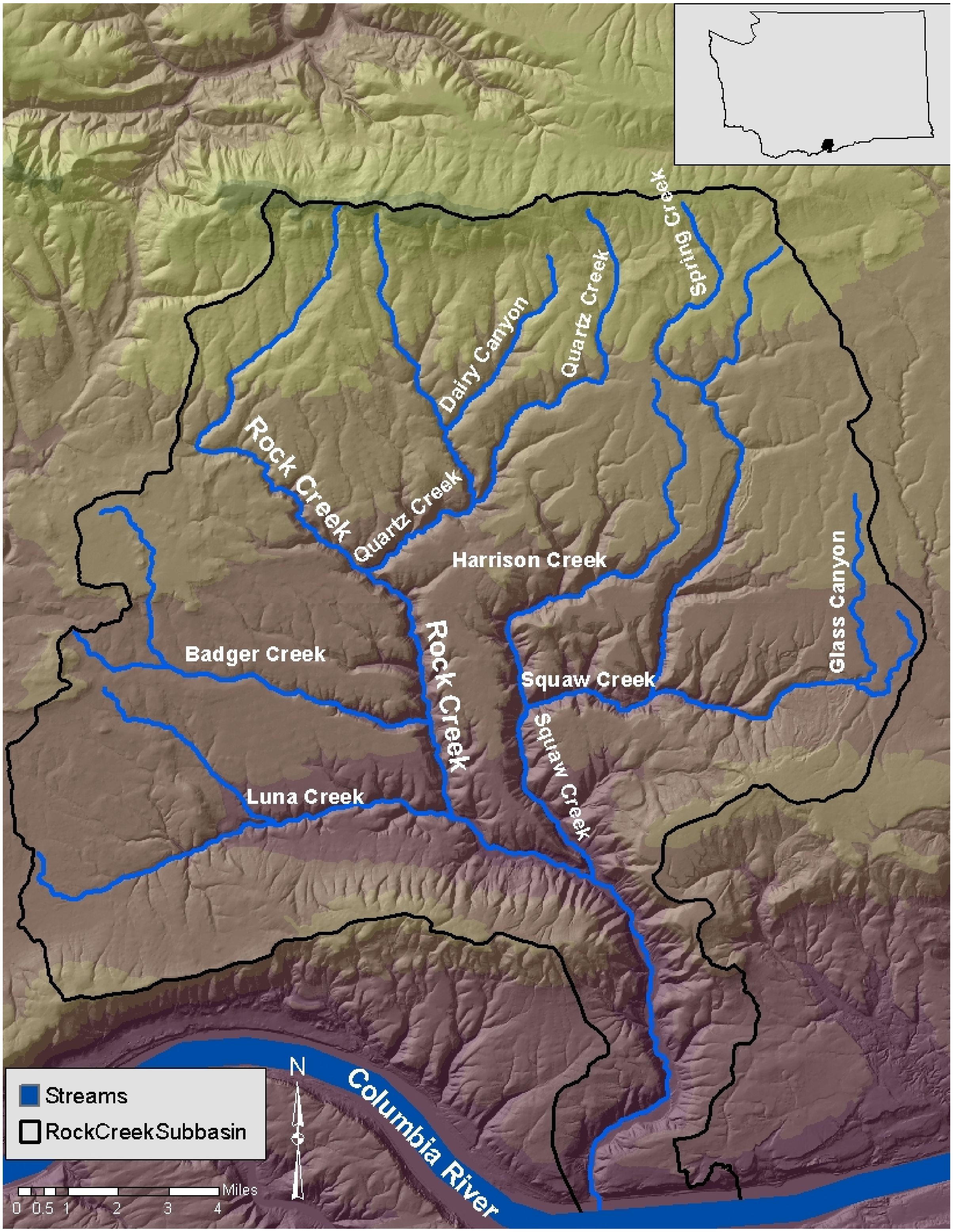

Figure 1. Rock Creek subbasin in southeastern Washington state.

Anadromous salmonid populations present in the Rock Creek subbasin include fall Chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon, summer steelhead (*O. mykiss*), as well as resident rainbow trout (*O. mykiss*). Rock Creek steelhead are listed as "threatened" under the Endangered Species Act (ESA), originally listed as part of the Middle Columbia River steelhead Evolutionarily Significant Unit (ESU) on March 25, 1999. Other native and non-native fish species are found primarily in the lower reaches of the subbasin (see Report A).

Synthesizing results from the combined assessments and modeling efforts of this project, a profile emerges of the Rock Creek subbasin as a challenging home for listed steelhead. In the lowest flow periods of 2010 to 2012, we found that an average of 36% of the surveyed streambed length was dry, and 17% remained as perennial pools with low habitat complexity. The maximum water temperature recorded in those pools for the most part did not exceed lethal limits for salmonids, and most pools had a maximum temperature that was lower than 21°C. *O. mykiss* were present in most pools, and non-native fish species, such as smallmouth bass (*Micropterus dolomieu*), were typically found downstream of river mile 3. Coho salmon were present in nearly every pool that was sampled in 2011, but were rare in the other survey years. Fish tested for disease were relatively healthy; therefore, disease does not appear to limit salmonid populations. About 27% of the 3,088 passive integrated transponder (PIT) -tagged *O. mykiss* and 38% of the 151 PIT-tagged coho were detected outmigrating as smolts, of which 92% migrated in April and May. As of November 2013, 9 *O. mykiss* and 4 coho that were tagged in Rock Creek as juveniles have returned as adults to Bonneville Dam on the Columbia River mainstem (RM 146). There is evidence that adult steelhead entering Rock Creek to spawn (February-March) have traveled in the mainstem Columbia River past McNary Dam (RM 292) throughout the winter, when the mainstem dams do not provide downstream passage except through turbines (see Report A). Continued operation of the PIT-tag detection units will allow us to estimate smolt-to-adult return rates for fish tagged in Rock Creek.

Access to fall Chinook and coho spawning habitat is inconsistent and limited to years when there is enough instream flow during their spawning period to connect Rock Creek to the mainstem Columbia River. Neither of those stocks appears to have viable populations in Rock Creek. Steelhead redds were observed in the mainstem Rock Creek from RM 1-RM 13.5, and in Squaw Creek from RM 0 – RM 5.5; i.e., virtually everywhere surveyed. Steelhead distribution in the basin may be more widespread; however, difficult access and lack of permission limited the range of surveys.

Genetic analyses indicate similarity between steelhead populations in lower Rock Creek and several exogenous regions of the Columbia River Basin, particularly the Snake River. There is sufficient evidence to conclude that out-of-basin genetic influences from stray fish are prevalent and spatially distributed throughout the surveyed range except above likely natural barriers. The results of the genetic analysis are supported by PIT-tag detections in Rock Creek which show that 85% of the adult steelhead detected were originally tagged or released in the Snake River (see Report A).

Many individual fish from the six downstream genetic analysis groups also assigned with high accuracy to the Rock Creek Subbasin, which may suggest that the subbasin still supports a distinct local genetic component. The disconnectedness of habitat during low-flow periods has no apparent bearing on the panmictic genetic composition of lower basin *O. mykiss* populations. There is a significant lack of out-of-basin genetic influence (i.e. anadromous fish) in fish collected in the mainstem Rock Creek 2.3 miles above the confluence with Quartz Creek (RM 17.7), and 7 miles above the confluence in Quartz Cr. Interestingly, collections from the mainstem RM 20 and Quartz Creek RM 7.5 were highly differentiated from each other and from the fish collected downstream in Rock Creek. It is likely that these two populations represent remnant Rock Creek resident *O. mykiss* that have undergone significant genetic drift, and that have been buffered from introgression (see Report D).

The EDT model offers a reasonable estimate of juvenile steelhead abundance (1,453 smolts, see Table C-4 in Report C), albeit lower than what was estimated during juvenile fish abundance sampling (between 1,545 smolts in 2012 and 2,785 smolts in 2011). The juvenile sampling estimate includes production from out-of-basin spawners, while the EDT modeling estimate does not. Nonetheless, this juvenile sampling estimate is lower than the likely total, since it does not include any production from upstream of RM 13.6 (Bickleton Bridge), including Quartz Creek, or other unsampled stream reaches.

The EDT model estimates adult abundance as 29 spawners; spawning surveys documented many more fish, although a large proportion of those were likely out-of-basin strays based on results of genetic analysis and PIT-tag detections. An estimate of productivity can be obtained once juvenile *O. mykiss* PIT-tagged in Rock Creek return as adults (data collection in progress). The EDT model also calculates current steelhead productivity and capacity to be reduced from historic conditions; however, there is uncertainty in estimating historic conditions.

The fish habitat in Rock Creek is spatially diverse (“patchy”) and variably suitable during the low-flow period, particularly in the more downstream reaches. Habitat limitations are modeled to affect nearly every life stage, though fry colonization and age-0 active rearing life stages are most heavily affected. This is due to the reduction in low-flow stream widths and the intermittency of surface flow that occurs as the fry migrate and begin to rear in the remaining perennial pools. Therefore, the most limiting habitat factor is instream flows during the low-flow period. The model suggests that the reaches with the greatest potential restoration benefit for steelhead abundance are low in the system, likely because more fish are affected in some part of their life history by conditions there compared with tributary or upstream reaches. However, restoration actions in the lower reaches have the potential to be ineffective or increase mortality by creating habitat traps (due to higher temperatures, increased presence of piscivorous species, and lack of water) if the specific restoration sites are not assessed on a finer scale than that used for the EDT modeling effort.

Prior to the efforts described in this report, very little was known about the threatened Mid-Columbia River steelhead population or the fish habitat conditions in Rock Creek, though some data gaps remain. We did not assess the fish population in the inundated portion of Rock Creek (RM 0-1.2). Estimates for survival of smolts passing from lower Rock Creek to the John Day Dam could be refined through additional PIT-tagging of juvenile salmonids and the installation of a PIT- interrogation system at the Highway 14 bridge (RM 0). A focused assessment of the influence of altered hydrologic and other habitat conditions and introduced predator species on salmonid survival within the inundated portion of Rock Creek would be needed to better understand to what extent this reach is a source of mortality for Rock Creek salmonids.

Through the efforts outlined in this report, we have determined that there is habitat available to consistently support salmonids throughout the basin, though the habitat in the lowermost 6 miles is less consistently suitable (depending on the water year and weather conditions) than farther upstream. Out-of-basin steelhead spawn in Rock Creek and appear to have overwhelmed the endemic population; however, genetically distinct populations of *O. mykiss* persist higher in the basin above likely passage barriers. Additional information from a separately funded geomorphic assessment (in progress) should help refine restoration opportunities. We anticipate the results of these combined efforts will support the priority actions and reaches for restoration and habitat protection.

1. Monitoring & Evaluation

The overall objective of the Monitoring and Evaluation effort was to gather baseline environmental and biological data throughout the subbasin to understand the current conditions of native salmonids and associated habitat conditions, and to identify opportunities for habitat restoration. This fish and habitat assessment was the first comprehensive assessment to be conducted in the Rock Creek subbasin. See Report A: *Fish Distribution and Population Dynamics in Rock Creek, Klickitat County, Washington*, and Report B: *Adult fish and habitat assessment*, respectively, for more details and discussion. Out-of-basin steelhead straying into the Rock Creek subbasin is covered in Report A and Report D, *Genetic evaluation of steelhead trout (Oncorhynchus mykiss) in the Rock Creek watershed of the middle Columbia River Basin*.

Report A: Fish Distribution and Population Dynamics in Rock Creek, Klickitat County, Washington

November 2009 – November 2013

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Abstract

The U.S. Geological Survey collaborated with the Yakama Nation starting in fall of 2009 to study the fish populations in Rock Creek, a Washington State tributary of the Columbia River 21 kilometers upstream of John Day Dam. Prior to this study, very little was known about the ESA-listed (threatened) Mid-Columbia River steelhead (*Oncorhynchus mykiss*) population in this arid watershed with intermittent stream flow. The objectives of the study were to quantify fish habitat, document fish distribution, abundance, and movement, and identify areas of high salmonid productivity. To accomplish these objectives, we electrofished in the spring and fall, documenting the distribution and relative abundance of all fish species to evaluate the influence of biotic factors on salmonid productivity and survival. We surveyed the distribution of perennial pools and established a network of automated temperature recording devices from river kilometer (rkm) 2 to 23 in Rock Creek and rkm 0 to 8 in Squaw Creek, a major tributary entering Rock Creek at rkm 13, to better understand the abiotic factors influencing the salmonid populations. Salmonid abundance estimates were conducted using a mark-recapture method in a systematic subsample of the perennial pools. The proportion and timing of salmonids migrating from these pools were assessed by building, installing, and operating two passive integrated transponder (PIT) tag interrogation systems at rkm 5 and at the confluence with Squaw Creek (rkm 13). From fall 2009 to fall 2012, we PIT-tagged 3,088 *O. mykiss* and 151 coho salmon (*O. kisutch*) during electrofishing efforts. In the lowest flow periods of 2010 to 2012, we found that an average of 36% of the surveyed streambed length was dry, and 17% remained as perennial pools. The maximum temperature recorded in those pools was 24.4°*C*, but most pools had a maximum temperature that was less than 21°*C*. *O. mykiss* were present in most pools, and non-native fish species, such as smallmouth bass (*Micropterus dolomieu*), were typically found downstream of rkm 5. Coho salmon were present in nearly every pool that was sampled in 2011, but were rare in 2009, 2010, and 2012. About 27% of the PIT-tagged *O. mykiss* and 38% of the PIT-tagged coho were detected outmigrating to the Columbia River. Of those fish, 92% (*n*=695) were detected leaving Rock Creek as smolts in April and May. As of November 2013, 9 *O. mykiss* and 4 coho that we tagged in Rock Creek as juveniles have returned as adults to Bonneville Dam. Also, an additional 34 PIT-tagged adult steelhead, and 6 PIT-tagged coho that were tagged by other groups have been detected in Rock Creek, of which, 22 were of known

origin (tagged as juveniles). Of these, 85% were tagged or released in the Snake River. The PIT-tag interrogation systems will be operated for several more years to allow time for the fish tagged as juveniles to return as adults and complete their life cycles. The Yakama Nation will use the information collected from this study to prioritize and gauge the effectiveness of ongoing and future restoration actions.

Introduction

Rock Creek is of great cultural significance to the Yakama Nation, and to the Rock Creek Band in particular. Oral history regarding historic runs of anadromous and resident fish, and perennial flows in the creek suggest that fish populations and habitat conditions have been significantly altered between historic and present conditions. Rock Creek has high potential productivity for steelhead, as evidenced by past spawning surveys conducted by the Yakama Nation (Harvey, 2013), but with significant habitat limitations such as low flow, high stream temperatures, and riparian, channel, and floodplain degradation (Lautz, 2000). Rock Creek was identified as critical habitat for the threatened Middle Columbia River Steelhead (*Oncorhynchus mykiss*) Distinct Population Segment (NOAA 2005). Though a potentially productive system, there were substantial gaps in knowledge about habitat conditions limiting fish populations in Rock Creek. For example, while steelhead spawner abundance was high in some reaches, prior to the initiation of this project there was limited information about where perennial fish habitat occurred in sufficient quantity and quality to produce the observed spawner abundance. Other than this BPA funded work, some information had been collected previously in Rock Creek as part of a larger habitat assessment of Washington Department of Ecology's Water Resource Inventory Area 31. A habitat survey and a single-pass snorkel survey were conducted in a subsample (14%) of Rock Creek for this watershed assessment (WPN 2009). The goal of the project was to gather baseline environmental and biological information throughout the accessible portions of Rock Creek to understand the distribution of the native salmonids and the habitat conditions. This information will aid in prioritizing sites for future restoration projects. This report describes the results of a cooperative study between U.S. Geological Survey (USGS) and the Yakama Nation that assessed the salmonid fish populations and habitat conditions in the Rock Creek. Specific objectives described in this report were to: 1) gather baseline information to determine juvenile anadromous and resident salmonid spatial distribution and relative abundance throughout the basin; 2) determine non-salmonid fish species presence and distribution, including lamprey; 3) monitor juvenile *O. mykiss* movement within Rock Creek and its tributary streams; 4) install and maintain two passive integrated transponder (PIT) tag interrogation systems and monitor movements of PIT-tagged juvenile fish through Columbia

River dams and estimate smolt-to-adult returns; 5) document pathogen presence and severity within the watershed.

Study Site Description

Rock Creek, a Washington State tributary that flows south to the Columbia River at river kilometer (rkm) 368, is 21 km upstream of John Day Dam. The watershed encompasses an area of 578 km^2. Lake Umatilla, the reservoir behind John Day Dam, inundates the lower 2 km of Rock Creek and is at 81 m in elevation. The headwaters of Rock Creek originate in the Simcoe Mountains, which are the watershed's northern border at 1,433 m in altitude, and are also the southern border of the Yakama Nation Reservation. The average annual precipitation in Rock Creek varies from approximately 25 centimeters at the mouth to 71 centimeters near the headwaters. Major tributaries to Rock Creek include Squaw Creek at rkm 13, Luna Gulch at rkm 18.5, and Quartz Creek at rkm 27. There is a Yakama Nation longhouse at rkm 6, and the primary land ownership within our study area was either Yakama Nation or privately owned. Rock Creek transitions from mountains and plateaus in the headwaters through deep canyon sections (200 to 500 m deep). Downstream of the canyon sections, Rock Creek emerges into a wider alluvial valley, which was about 1.5 km downstream of the Goldendale to Bickleton Highway Bridge (hereafter referred to as the Bickleton Bridge). The reaches that were included in this fish assessment were, Rock Creek from rkm 2 up to Bickleton Bridge at rkm 22 (excluding private land ownership at rkm 3.3 to 4.8), Squaw Creek up to rkm 9, and Luna Gulch to rkm 0.5 (Figure A-1). Adjacent to the riparian zone, the plant community is sagebrush-steppe, and the dominant land use was cattle grazing. The riparian vegetation in this area is primarily composed of alder and willow, white oak, and non-native black walnut; however portions of the riparian area are also un-vegetated. Due to the deeply incised canyon upstream of Bickleton Bridge, access for stream sampling was difficult. However, we conducted additional fish surveys in Rock Creek at rkm 32 and in Quartz Creek at rkm 12. We also accessed Rock Creek at the Quartz Creek confluence to deploy temperature recording devices in 2010. From 2009 through 2012, much of the watershed had intermittent stream flow from June through October. However, there was perennial stream flow from confluence with Quartz Creek to approximately1.5 km downstream of the Bickleton Bridge (where the wider alluvial valley begins) and there were many isolated perennial pools throughout the rest of the watershed.

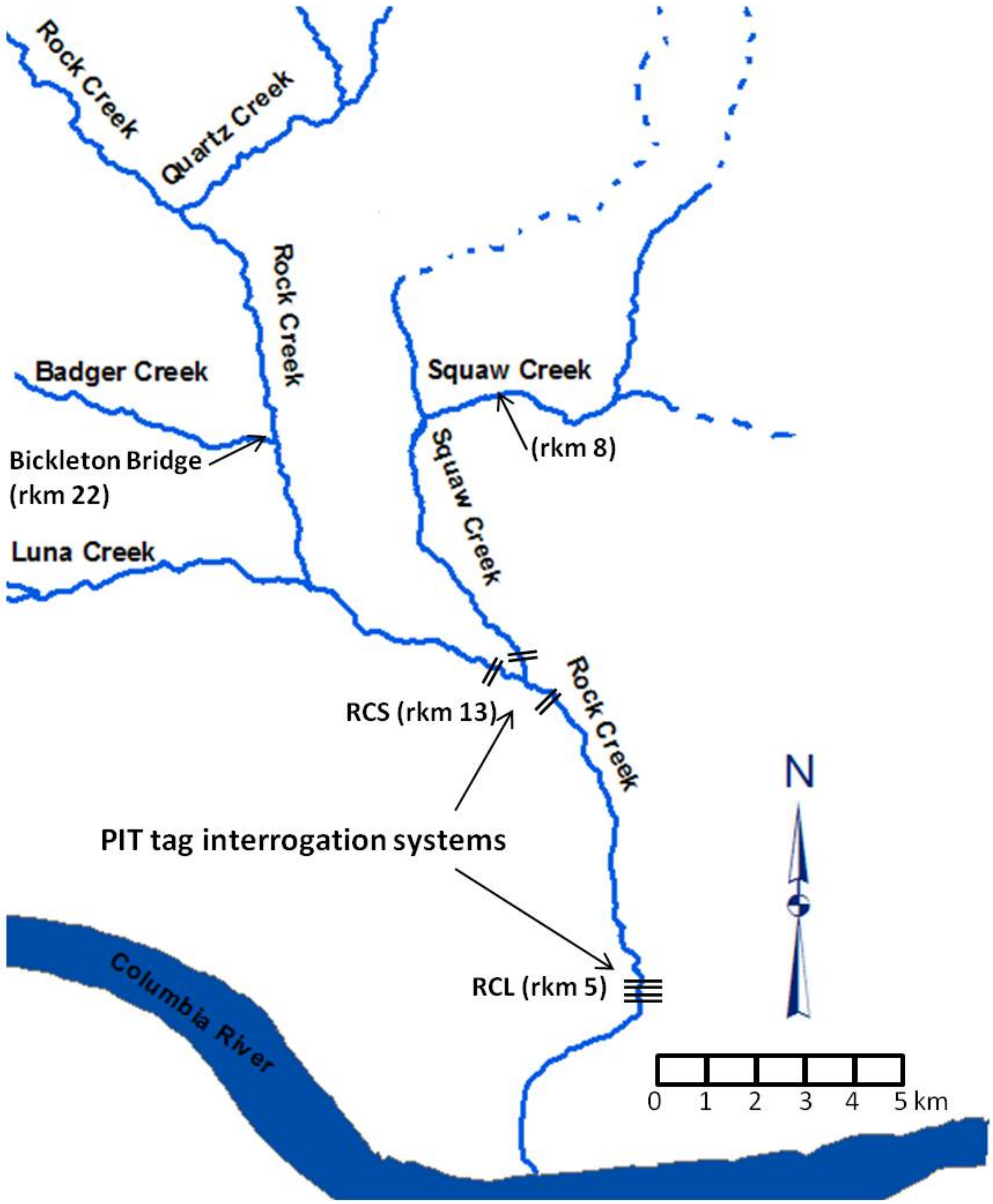


Figure A-1. A map of the locations of tributary streams, PIT-tag interrogation systems at river kilometer (rkm) 5 (RCL) and 13 (RCS), and the most upstream fish sampling locations (Bickleton Bridge, and Squaw Creek at rkm 8) in Rock Creek, Washington.

Methods

Stream Pool Habitat Surveys

We conducted a habitat survey of all stream sections up to river rkm 22 for which we had permission to survey during the fall of 2010, 2011, and 2012. The surveys started where Rock Creek and the backwater caused by John Day Dam converge (rkm 2) and ended at the Bickleton Bridge. In 2010, an additional 1.7 km were surveyed upstream of the Bickleton Bridge. During these surveys we measured the length of all dry sections, the length of all non-pool wet sections, and the pool length, pool wetted width, average residual pool depth, and maximum residual pool depth. This allowed us to identify the pools to be randomly selected for fish sampling and to quantify and document the spatial distribution of perennial fish habitat during the limiting time of year. In addition to the year-round water temperature monitoring done by the Yakama Nation, summer water temperature data was collected in the pools where we anticipated that population estimates for salmonids would occur. We used Hobo Tidbit and Stowaway automated temperature recording devices (Onset Computer Corporation, Bourne, MA) at up to 18 pools in Rock, Squaw, and Quartz creeks during June-September of 2010-12.

Fish Sampling

Fish species distribution, relative abundance, length-frequency, weights, and salmonid population density were determined by backpack electrofishing randomly selected pools. We used a stratified, randomized systematic sampling design to determine which pools to sample. In the fall, habitat surveys were conducted prior to electrofishing to measure the length, width, and depth of pools and non-pools in all anadromous fish-bearing reaches where we had landowner permission and access. Sampling was limited to pools because the riffles were too shallow to hold fish or sample in the fall when temperatures were appropriate for electrofishing. We randomly selected the starting pool (first, second, or third) and systematically electrofished every third subsequent pool greater than 70 cm in maximum depth. Fish sampling consisted of single-pass electrofishing upstream from the pool tail-out to the pool head and back downstream to the tail-out within each pool. In the fall, mark-recapture population estimates were conducted in a total of 12 randomly selected pools in 2011 and 14 pools in 2012. When possible (perennial both years) population estimates were conducted in the same pools. Four pools in the reach of Rock Creek downstream of the confluence with Squaw Creek, four pools in the reach of Rock Creek upstream of the Squaw Creek confluence, and four pools in Squaw Creek in 2011, and six pools in Squaw Creek in 2012 were selected for mark-recapture fish population estimates. Fish sampling and PIT tagging was also conducted in additional pools to learn about fish distribution, relative abundance, and movement.

Pools were electrofished using a battery-powered Smith-Root model 12-B backpack electrofisher (Smith Root Inc., Vancouver, WA). The electrofisher settings of voltage, frequency, and duty cycle were determined by the physical characteristics of the site (water conductivity, creek size, water volume, etc.). The lowest effective electrofisher settings were used in order to minimize fish injury. The electrofisher settings were typically 60 hz, 6 milliseconds, and 300 V. Two to three crew members with dip nets remained downstream from the electrofisher and netted stunned fish. We attempted to capture all observed age-1 and older *O. mykiss,* a subset of age-0 *O. mykiss,* and a subset of any other fish species observed while electrofishing to determine fish species composition in each pool. All captured fish were immediately placed into plastic buckets filled with ambient stream water and fitted with aerators. Captured fish were anesthetized with the lowest possible dose of tricaine methanesulfonate (MS-222) before handling (about 50 mg/L MS-222). Because the effectiveness of MS-222 as an anesthetic varies with factors such as temperature and fish density, the concentration of anesthetic was adjusted. Adjustment of the anesthetic concentration was based on the amount of time it takes for a group of fish to lose equilibrium. The goal was for the induction time to be between 1 and 5 minutes. After handling, the fish were placed in a 5 gallon bucket fitted with aerators and filled with ambient stream water where they were held until they fully regained equilibrium. After the fish recovered, they were released back to the pool where they were captured. The exception to this protocol was when a fish died before or during handling. These mortalities were transported to the U.S. Fish and Wildlife Service's Lower Columbia River Fish Health Center (LCRFHC) for disease profiling. The fish received by the LCRFHC were given a rigorous inspection for disease. Diseases screened at the LCRFHC by testing or microscopic observations included bacterial (bacterial kidney disease, coldwater disease, columnaris, emphysematous putrefactive disease, furunculosis, enteric redmouth), viral (infectious pancreatic necrosis, infectious hematopoietic necrosis, viral hemorrhagic septicemia), and parasitic agents (whirling disease, *Ceratomyxa*, digenetic trematodes, *Myxobolus kisutchi*, *Myxidium minteri*, *Hexamita, Gyrodactulus*, *Scyphidia*, *Heteropolaria*). After completion of the electrofishing survey, the length, width, average depth, and maximum depths were measured in each pool where population estimates were conducted.

After anesthetizing, all captured fish were identified to the species level, scanned for PIT tags, measured for fork length (FL) to the nearest mm, weighed to the nearest 0.1 g, and inspected for external signs of disease. Tissue samples (fin clip) from a subsample of salmonids were preserved for genetic analyses. Genetic samples were submitted to the Columbia River Inter-Tribal Fish Commission (CRITFC) for analysis. In order to individually mark fish to track movements, estimate abundance, and measure growth, we inserted PIT tags (12 mm; 134.2 kHz) in the peritoneal cavity of salmonids that exceeded 70-mm FL. All PIT tagging followed the procedures outlined by Columbia Basin Fish and Wildlife Authority (1999). All PIT-tag data were entered in the PTAGIS database, maintained by Pacific States Marine Fisheries Commission (PSMFC 2009). To mark salmonids less than 70-mm FL, we stained them with 16 mg/L Bismarck Brown Y biological stain (Sigma Chemical Company, St. Louis, Missouri) for approximately 20 minutes. During the recapture pass the following day, unmarked salmonids exceeding 70-mm FL were PIT tagged, but unmarked salmonids less than 70 mm were returned to the stream unmarked. In 2012, we marked smallmouth bass and northern pikeminnow with Bismarck Brown to estimate abundance.

Population Estimates

We estimated population density and biomass of salmonids by using the mark-recapture method as detailed in Temple and Pearsons (2007). We anchored block nets, with each spanning the creek, at the upstream and downstream end of each pool. The nets were constructed of 3-mm knotless nylon mesh. The weighted line of each net was secured to the stream bottom with cobble and boulders. Sticks or other material were used to prop up each net at least 0.5 m above the water surface. This was done to ensure no fish immigration or emigration (i.e., closed population) during the estimate. Each pool was electrofished via an upstream and downstream pass and all captured salmonids were marked, returned to the sampled pool, the block nets were cleaned and left overnight, and the pool was re-electrofished to recapture fish the following day. This allowed for a minimum recovery period of 18 hours.

For our mark-recapture data analysis, we estimated the abundance of age-0 (< 95 mm FL) and age-1 or older (> 95 mm FL) salmonids as follows:

$$N = [(M + 1)*(C + 1)/ R + 1] - 1,$$

where, M = number of fish marked on the first sample, C = number of fish captured in the second sample, and R = number of marked fish captured in the second sample (Chapman 1951). The confidence interval of each estimate was calculated using a normal approximation; however, we used a binomial distribution when R/C was greater than 0.10 (Seber 1982).

We initially intended to conduct population estimates for salmonids in pools in the spring of each year, beginning in 2010; however, they were not completed and no other spring population estimates were attempted. When setting block nets to ensure a closed population during the spring 2010 mark-recapture population estimate, an unexpected thunder storm occurred overnight that increased stream discharge, causing age-0 *O. mykiss* to move and become impinged on both the upstream and downstream block nets. The resulting mortality of these age-0 fish exceeded the “take” for steelhead as permitted by the National Marine Fisheries Service (NMFS). In response to this event, the NMFS scientific collection permit did not allow us to sample fish in the fall of 2010. We did not attempt other population estimates in the spring of 2011 and 2012 to eliminate the potential for another similar mortality event. We successfully conducted population estimates in the fall of 2011 and 2012. However, we limited the number of age-0 *O. mykiss* that were handled to a representative subsample of about 15 per pool in the spring and in the additional pools that were electrofished without conducting population estimates in the fall. This was done to minimize the number of *O. mykiss* that were handled, while collecting a sufficient sample size to create length-frequency histograms.

PIT-tag Interrogation

To evaluate timing and degree of salmonid movement, smolting success, adult stray rates, and other life history attributes, we installed two multiplexing PIT-tag interrogation systems (PTISs) in Rock Creek in the fall of 2009. These PTISs were built and installed by USGS and maintained and downloaded by the Yakama Nation. One PTIS was installed near the Rock Creek Longhouse at rkm 5 (RCL) and powered by grid power, with three arrays in an upstream to downstream orientation that were each two antennas wide. The other PTIS was installed at the confluence with Squaw Creek at rkm 13 (RCS) and was powered by a solar panel array. The

RCS PTIS was installed with one array that was two antennas wide and 40 m upstream of Squaw Creek, one array of two antennas that was 20 m downstream of Squaw Creek, and two single antennas in Squaw Creek about 3 m apart and 5 m upstream of the confluence. All antennas at both sites were 6.1-m long, 1-m wide, and were attached flat to the substrate with a variety of anchoring methods. The PTIS transceivers were Destron-Fearing 1001M (MUX) that can power up to six 6.1 m long antennas. These transceivers detected 134.2 kHz full-duplex tags, the standard PIT tag type used in salmonids in the Columbia River basin. To reduce electrical interference within the PITSs, grid power or solar panels were connected to a charging circuit that contained two banks of batteries (each bank consisted of two 12V batteries wired in series for 24V) and a switching mechanism to alternately charge one bank of batteries while the other bank was isolated from the charging circuit and powering the MUX. To protect the MUXs from the high summer air temperatures, these systems were removed from July through October when the stream-bed was dry and pools were disconnected, thus eliminating the opportunity for fish movement.

Survival Estimates and Detection Probability

Survival estimates were calculated for fish that were PIT tagged in Squaw Creek, Rock Creek above the Squaw Cr. confluence, and Rock Cr. below the Squaw Creek confluence from 2009 through 2012. These estimates were based on PTIS detections over time using Cormack-Jolly-Seber estimates (Cooch and White 2010) from the program MARK (Colorado State University, Fort Collins, Colorado). In the context of survival estimates, the passive detection of PIT-tagged smolts at any other PTIS downstream of tagging location was considered a “recapture”. Recapture data of fish tagged in Rock Creek were downloaded using the PTAGIS database maintained by PSMFC. We then used the PitPro software (Westhagen and Skalski 2007, http://www.cbr.washington.edu/paramest/pitpro/) to transform the data from PTAGIS into individual capture histories formatted for the program MARK. Models of survival were then compared using AICc analysis and ranked based on Delta AICc (Burnham and Anderson 2002). Delta AICc models were selected for consideration depending on how they ranked on Burnham and Anderson’s three level scale (0-2 substantial support, 4-7 considerable support, >10 essentially none). Cormack-Jolly-Seber survival estimates were a combination of both survival and fish emigration. The estimate at the first potential site for detection (usually the first site downstream of where the fish was tagged, RCS for fish tagged upstream of rkm 13 or in Squaw Creek, and RCL for fish tagged in Rock Creek from rkm 5 to 13) was considered to be the apparent survival. This apparent survival estimate includes fish that died prior to emigrating as well as fish that exhibit a resident life history and do not migrate to the first potential site for detection. We assumed that any fish that began to migrate and was detected at RCS continued through all potential detection sites down to the Columbia River estuary. Any fish that stop to rear and cease migration (potadromous *O. mykiss* for example) would be evaluated as mortalities for these survival estimates.

Results

Habitat

We surveyed 24.5 to 28.8 km of stream per year in the fall of 2010 through 2012 (Table 1). The differences in surveyed length were due to changing landowner permissions for access and changes in the length of the thalweg in the primary channel. The percent of the streambed that was dry ranged from as little as 23% in Rock Creek from rkm 13 to 22 in 2010 to as much as 53% in Squaw Creek from rkm 0 to 9 in 2012. The number of pools per 100 m varied from as few as 0.53 pools per 100m in Rock Creek (rkm 0 to 12) and Squaw Creek (rkm 0 to 9) to as many as 0.85 pools per 100m in Squaw Creek in 2010. Compared to the other two reaches, the lower Rock Creek (rkm 2 to 12) reach had the greatest percent of pool by length (23 to 28%), and the greatest average maximum depth in all years (Table A-1). The year with the greatest amount of pool habitat was 2010, with the greatest percent of pool habitat by length in each reach (Table A-1). The average of the mean pool depths in each reach was similar among reaches and years. Most of the habitat that was non-pool wet was too shallow for salmonids to inhabit or migrate through, but it did indicate the areas where the water table remains near the streambed surface during the low flow period (Figure A-2).

Table A-1. Length of stream that was dry, non-pool wet, or pool, along with the average maximum depth, and mean depth of pools in Rock Creek, WA during September of 2010-2012.

	Rock Creek rkm 2-13[a]			Rock Creek rkm 14-22			Squaw Creek rkm 0-9		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
Total stream length surveyed (m)	7,542	11,001	9,541	8,484	8,930	8,895	8,438	8,888	8,567
Length dry (m)	2,166	3,513	4,102	2,337	3,271	3,726	3,512	2,599	4,550
Percent dry	29	32	43	27	37	42	42	29	53
Length non-pool that was wet (m)	3,302	4,743	3,281	4,551	4,304	4,002	3,753	5,114	3,158
Percent non-pool that was wet	43	43	34	53	48	45	44	58	37
Number of pools	54	58	60	68	49	45	72	56	45
Number of pools/100 m	0.72	0.53	0.63	0.80	0.55	0.51	0.85	0.63	0.53
Total length of pools (m)	2,074	2,745	2,158	1,596	1,355	1,167	1,172	1,175	859
Percent pools by length	28	25	23	19	15	13	14	13	10
Average pool length (m)	39	47	36	23	28	26	16	21	19
Average pool area (m^2)	302	387	260	136	144	125	65	75	78
Average max depth of pools (cm)	69	78	75	62	62	64	53	54	59
Average mean depth of pools (cm)	34	38	43	32	28	36	31	27	32

[a] Surveys were not done downstream of rkm 4.8 in 2010. In 2012, surveys were not done between rkm 3 and 4.8.

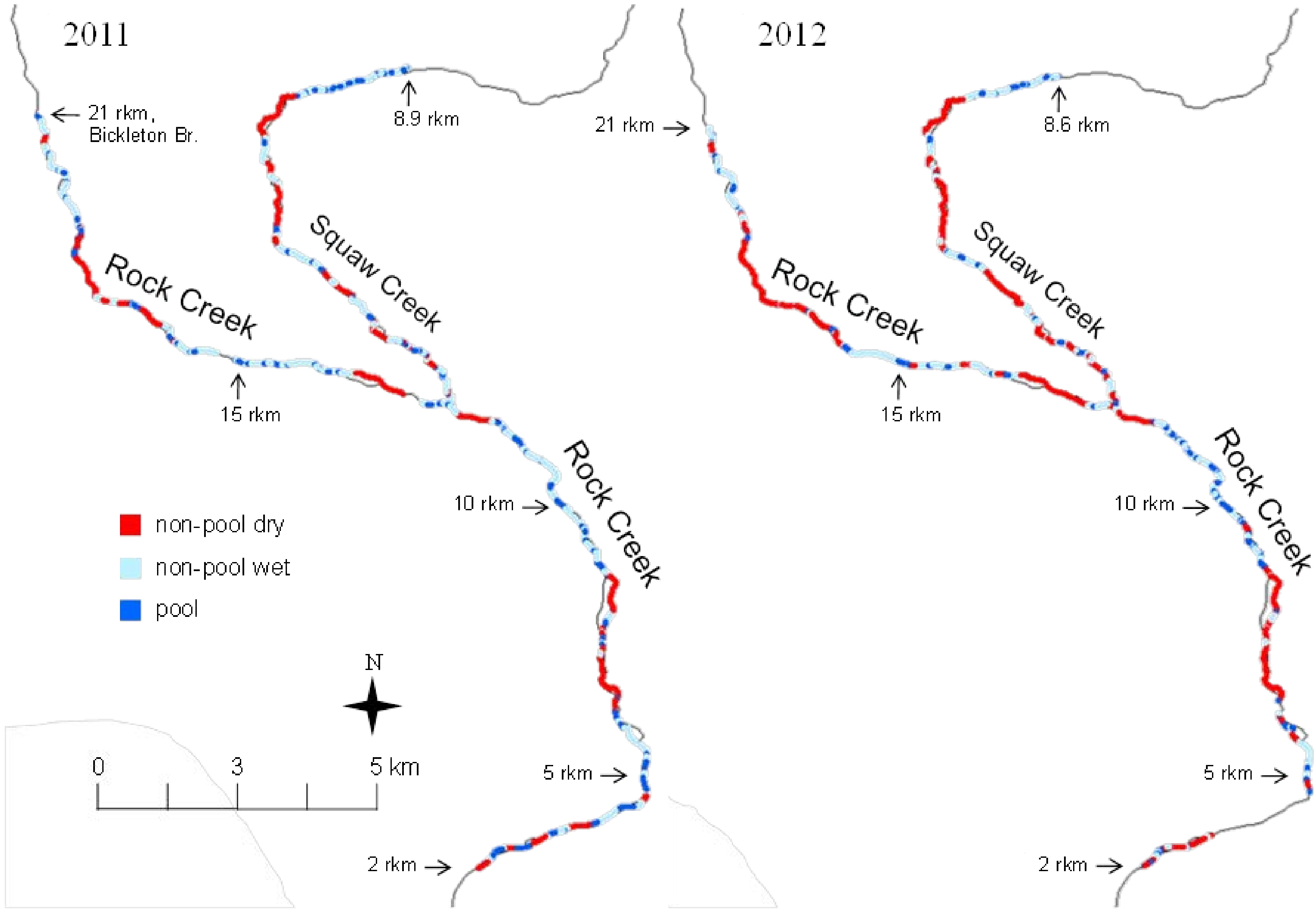


Figure A-2. Maps of Rock Creek from river kilometer (rkm) 0 to 21, and Squaw Creek to rkm 9 showing the location and lengths of streambed sections that were non-pool dry, non-pool wet, and pool habitats during early September 2011 and 2012. Maps courtesy of A. Matala and D. Graves (Columbia River Inter-Tribal Fish Commission).

The sections of Rock and Squaw creeks that remained wetted during summer low flow were consistent between survey years (Figure A-2). This was true even though, in nearly every year (March 2012 in particular), there was a flood that caused noticeable bed load movement that which moved gravel to fill in pools, scour new pools, and altered length of the primary thalweg. This changed the number, depth, and location of many pools in Rock Creek (Figures A-3 through A-5) In Figures A-3, A-4, and A-5, the exact lengths along the thalweg in between wet and dry sections did not match up precisely. This was due to changes in thalweg length and field personnel survey estimates. However, the patterns of wet and dry sections from each survey year do match when re-aligned at known references, such as Newell Springs or the Harrison Creek confluence for example (Figure A-5). This indicated that the locations of stream sections that remain in contact with the groundwater were consistent from year to year. In 2010, we surveyed an additional section of Rock Creek above and below the Quartz Creek confluence (from rkm 26 to 28) and Quartz Creek from rkm 0 to 1.3 (Figure A-6). The riffles in this area remained perennially wet, and while no fish sampling was conducted in this area due to steep and challenging access routes, age-0 and age-1 and older *O. mykiss* were readily observed in the pools.

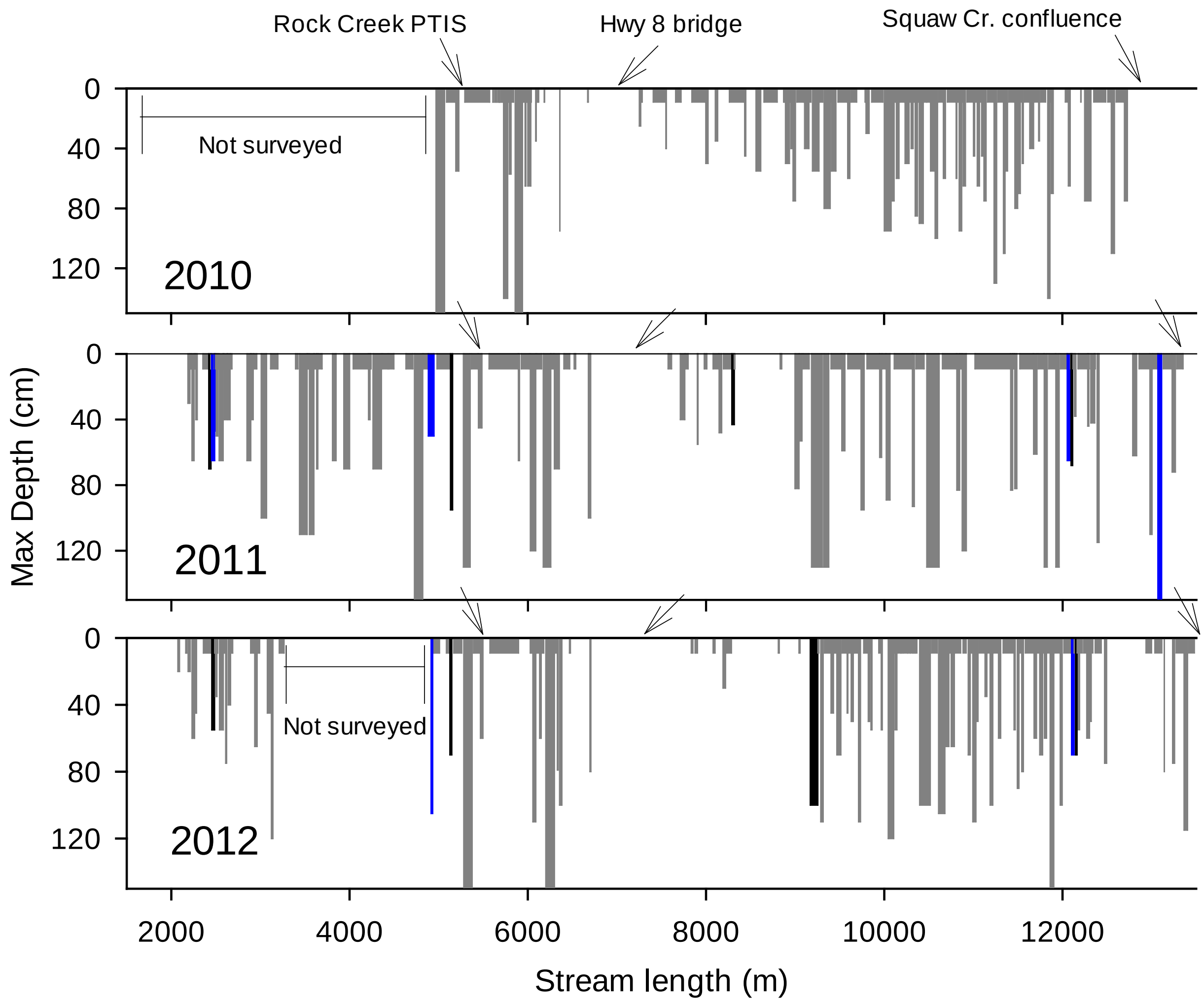


Figure A-3. The length of stream thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar heights showing maximum depth of each pool) from river kilometer 2 to 13 of Rock Creek, WA during early September of each year. Pools indicated by blue bars were sampled for fish and pools indicated by black bars were sampled for fish population estimates. The arrows point to sites that are labeled on the top figure. The width of each bar indicates individual pool lengths.

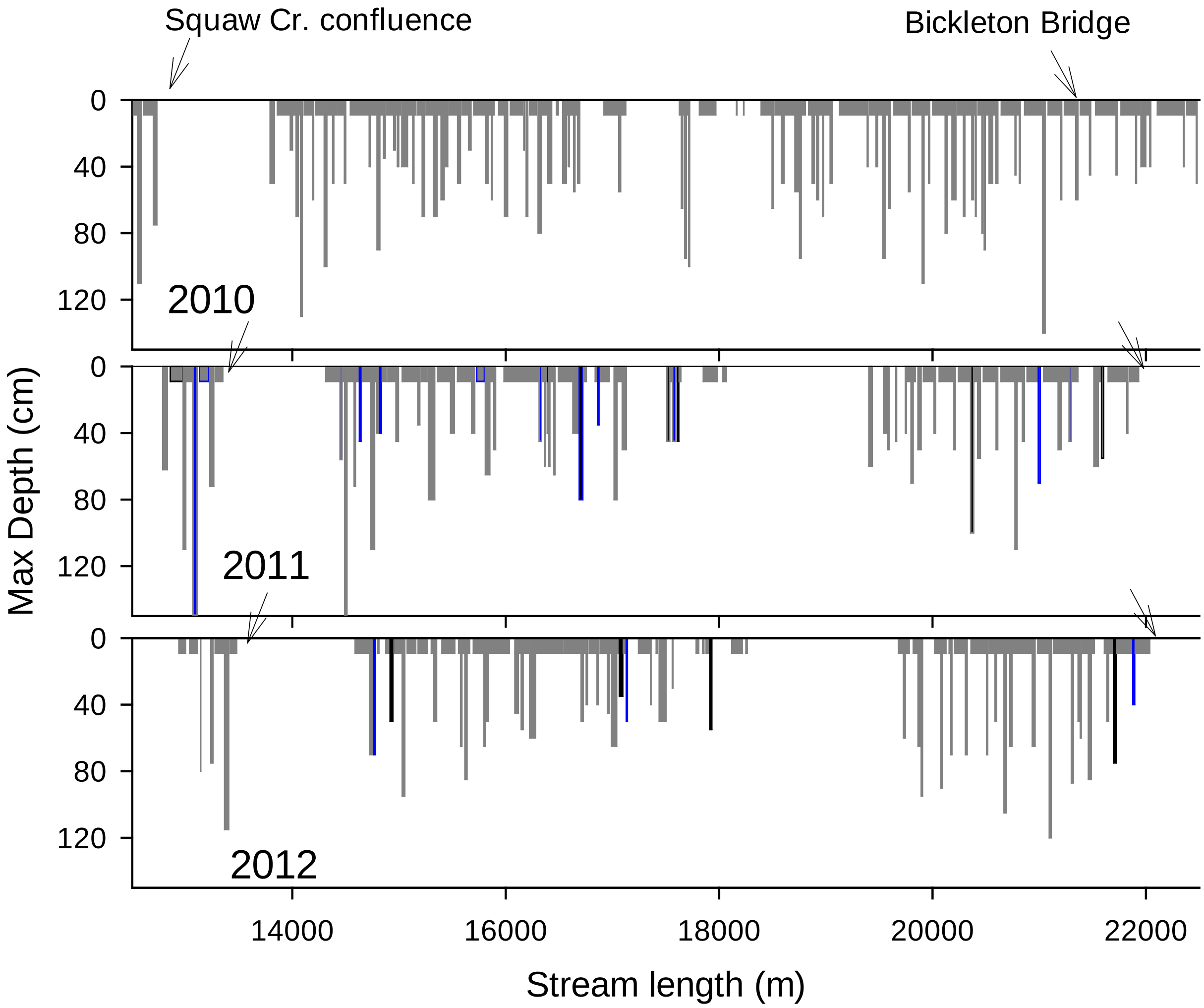


Figure A-4. The length of stream thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar heights showing maximum depth of each pool) from river kilometer 13 to 22 of Rock Creek, WA during early September of each year. Pools indicated by blue bars were sampled for fish and pools indicated by black bars were sampled for fish population estimates. The arrows point to sites that are labeled on the top figure. The width of each bar indicates individual pool lengths.

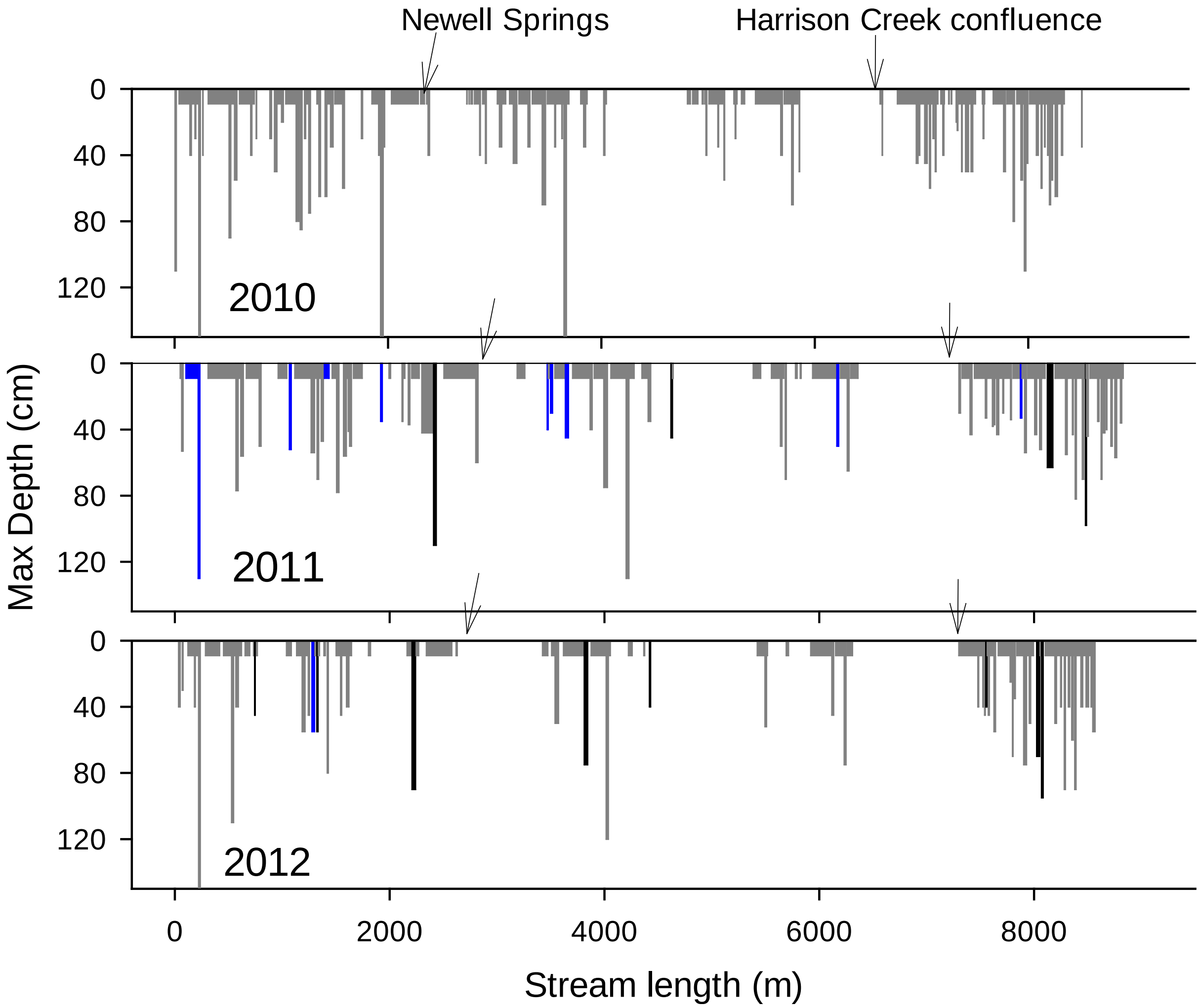


Figure A-5. The length of stream thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar heights showing maximum depth of each pool) from river kilometer 0 to 9 of Squaw Creek, WA during early September of each year. Pools indicated by blue bars were sampled for fish and pools indicated by black bars were sampled for fish population estimates. The arrows point to sites that are labeled on the top figure. The width of each bar indicates individual pool lengths.

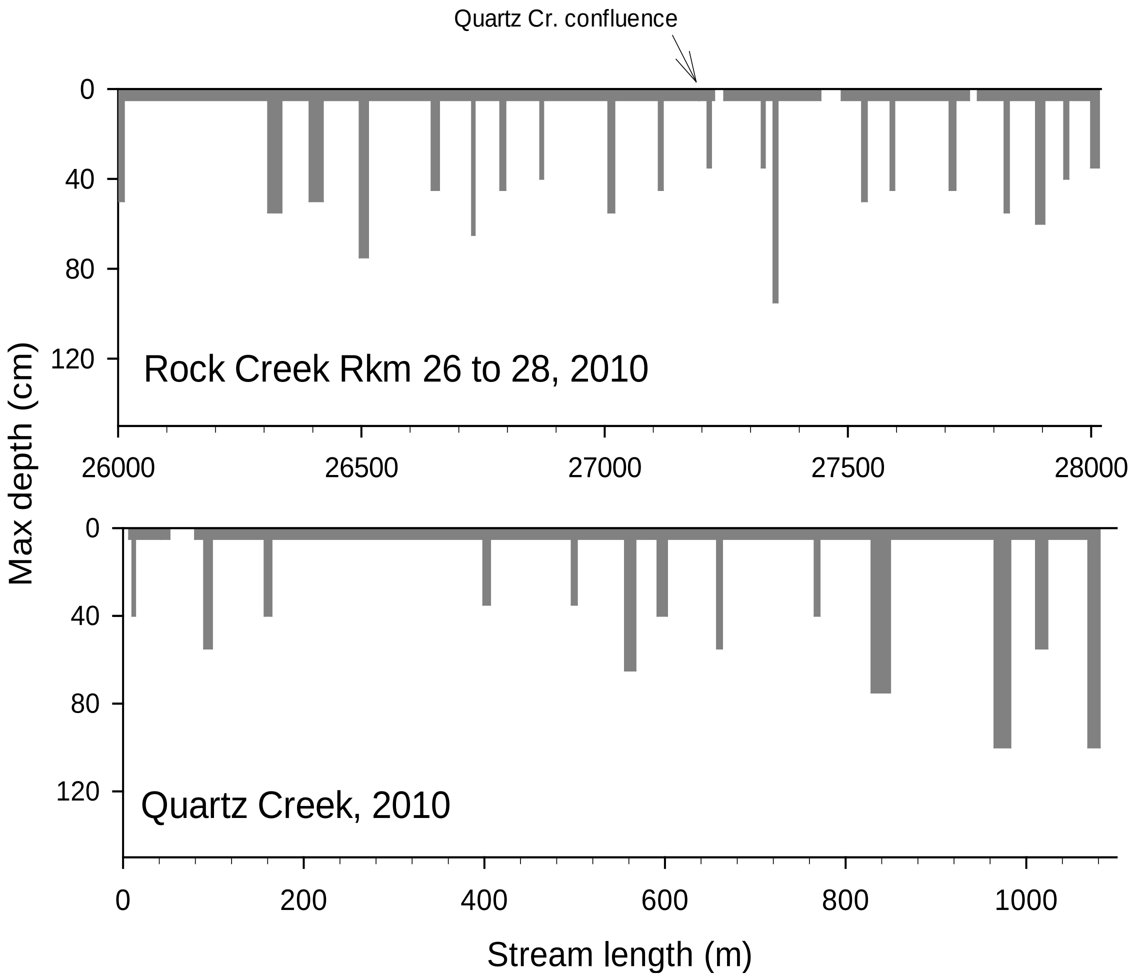
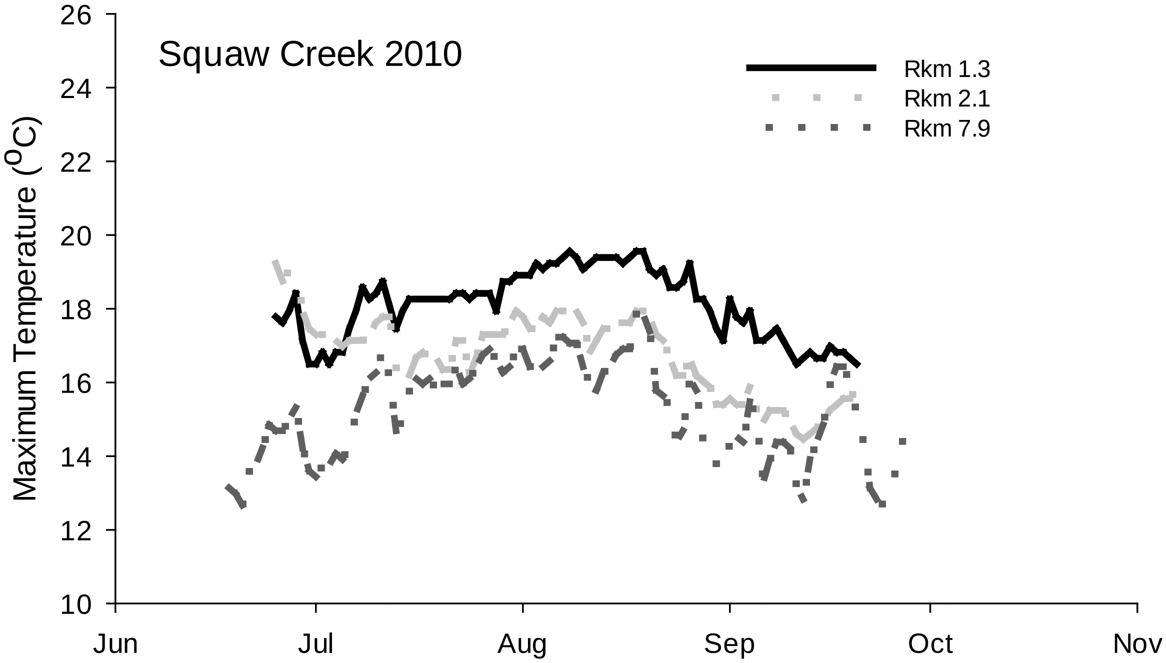


Figure A-6. The length of stream thalweg that was dry (blanks, 5% for Rock Cr., 4% for Quartz Cr.), non-pool wet (bars of equal length, 82% for Rock Cr., 87% for Quartz Cr.), and pool (variable bars showing maximum depth of each pool, 13% for Rock Cr., 9% for Quartz Cr.) from river kilometer 26 to 28 of Rock Creek and river kilometer 0 to 1 of Quartz Creek, WA on September 30, 2010. The width of each bar indicates individual pool lengths.

Water temperatures were warm, but were unlikely to be hot enough to be lethal for *O. mykiss* in Rock and Squaw creeks, with cooler temperatures in the upstream reaches, as expected. Temperatures were collected at about 18 locations in Rock and Squaw creeks during July-September of 2010 through 2012. Additional year-round water temperatures were collected in Rock Creek by the Yakama Nation and are presented in that chapter of this report. As examples of the temperature regime through the summer months, Figures A-7 through A-10 show representative water temperatures in Rock and Squaw creeks in 2010 through 2012. These were typically the same locations where population estimates of salmonids occurred. This additional temperature monitoring aided in understanding how temperatures may have influenced fish distribution and population abundance in individual pools. A 16°*C* limit for surface water has been set by the Washington Department of Ecology as in indicator of stream health for salmonid habitat and a 20°*C* limit for non-salmonid habitat (Washington Department of Ecology, Chapter 173-201A, Water Quality Standards for the Surface Waters of the State of Washington). We recorded water temperatures that exceeded 16°*C* at all of the sites in 2010 through 2012. Water temperature at 10 and 9 of 18 sites exceeded 20°*C* in 2011 and 2012 respectively (Table A-2). In 2010, only six of the 18 sites exceeded 20°*C*; however, six of the sites were higher in the watershed (Quartz Creek and Rock Creek near Quartz Creek confluence) in locations that were not repeated in 2011 and 2012 (Table A-2). Maximum water temperatures were above 16°*C* for 80 to 90 days up to rkm 18 during 2010, 2011 and 2012 (Table A-2). The maximum water temperature that was recorded in Rock Creek was 24.4°*C* at rkm 4.8 in 2012. Temperatures were slightly less warm in Squaw Creek, with a maximum recorded temperature of 23.5°*C* at rkm 0.8 in 2011. In general, Rock Creek water temperatures downstream of the Squaw Creek confluence exceeded 20°*C* maximum more than upstream of the confluence or in Squaw Creek. However there were a few pools that were exceptions, such as rkm 14.7 in Rock Creek (28 days with maximum temperature above 20°*C*) and rkm 3.7 in Squaw Creek (29 days with maximum temperature above 20°*C*). Tidbits that were in pools that became shallow or that were exposed to direct sunlight recorded the highest temperatures during this time period, as expected. Not all Tidbits placed in pools that we selected for monitoring remained under water for the duration of the summer, with between three and five Tidbits going dry each year (Table A-2).



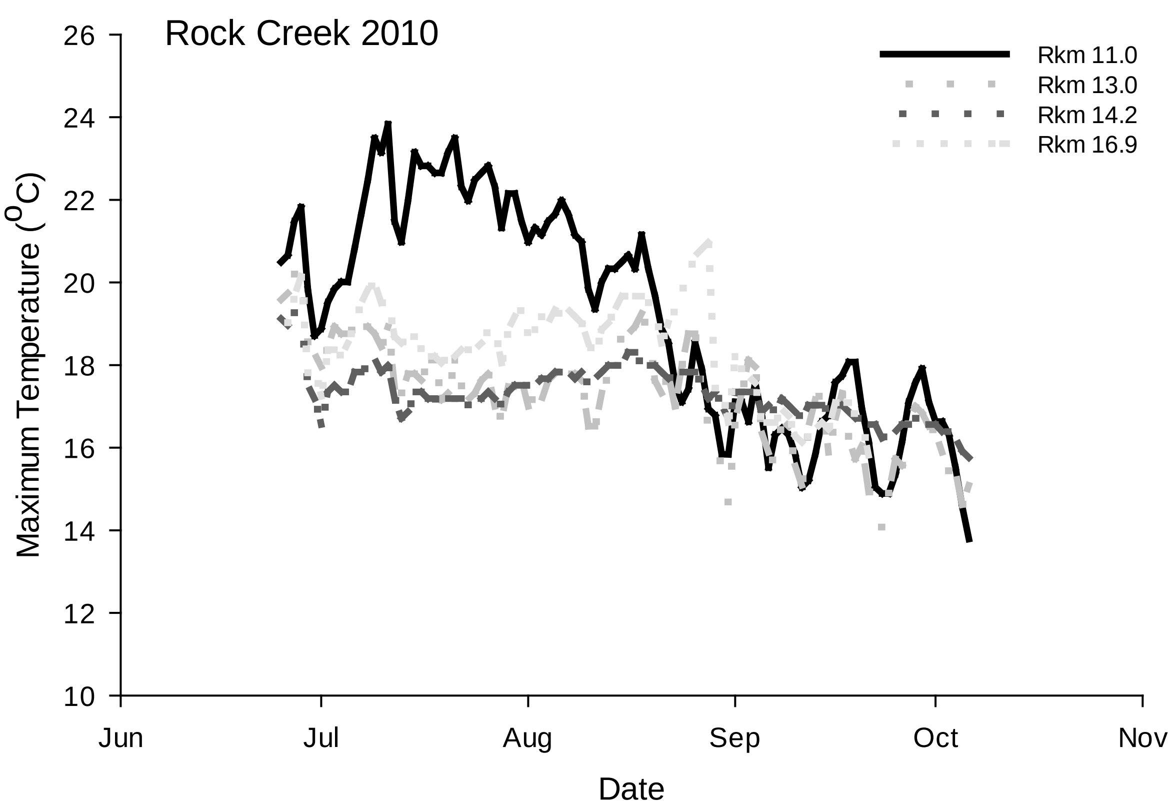


Figure A-7. Representative maximum daily water temperatures in Rock Creek and Squaw Creek, WA during summer 2010. See Table A-2 for additional temperature information.

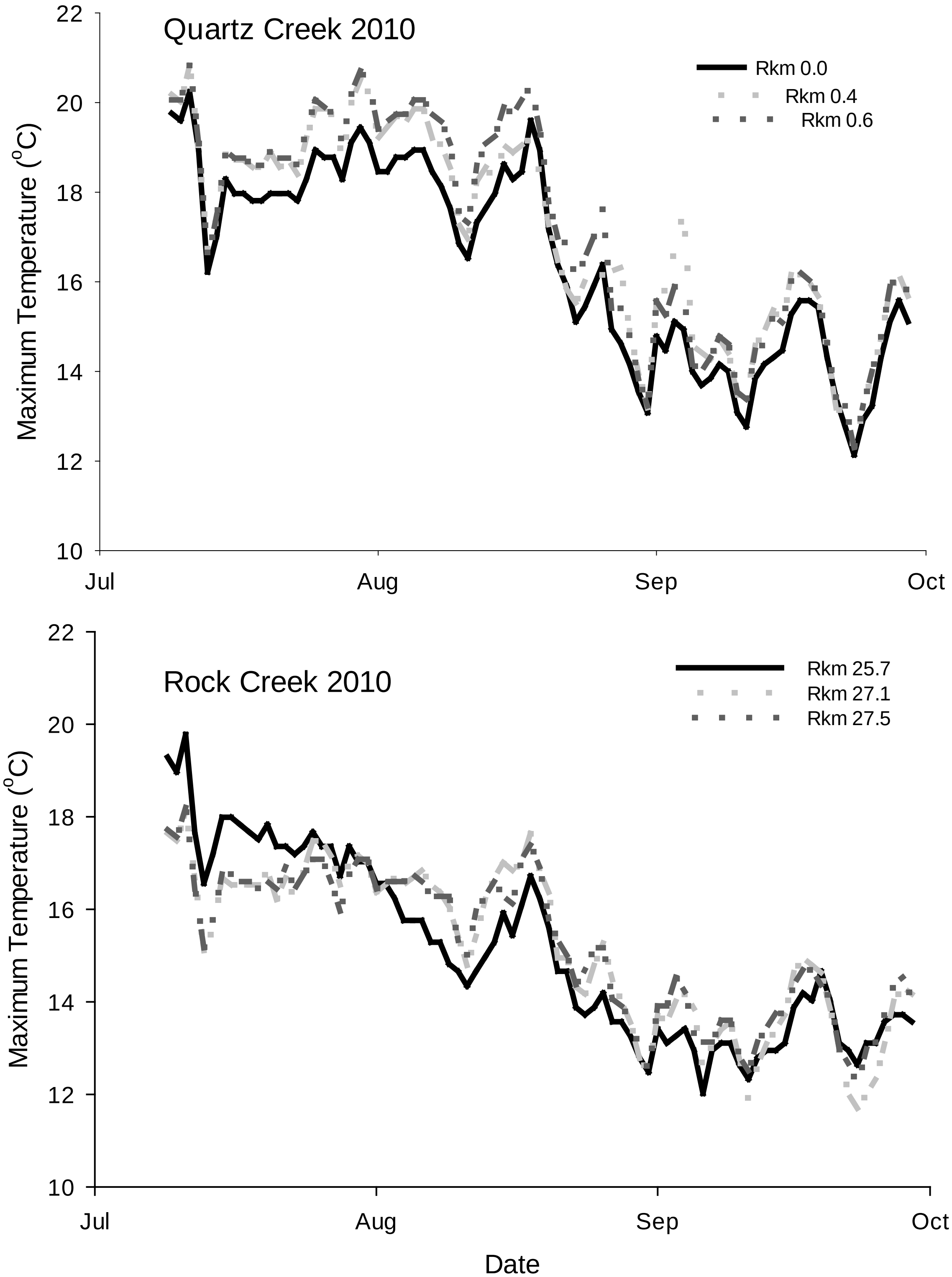


Figure A-8. Maximum daily water temperature in Rock Creek at river kilometer (rkm) 25 to 27 and Quartz Creek rkm 0 to 1, WA during summer 2010. See Table A-2 for additional temperature information.

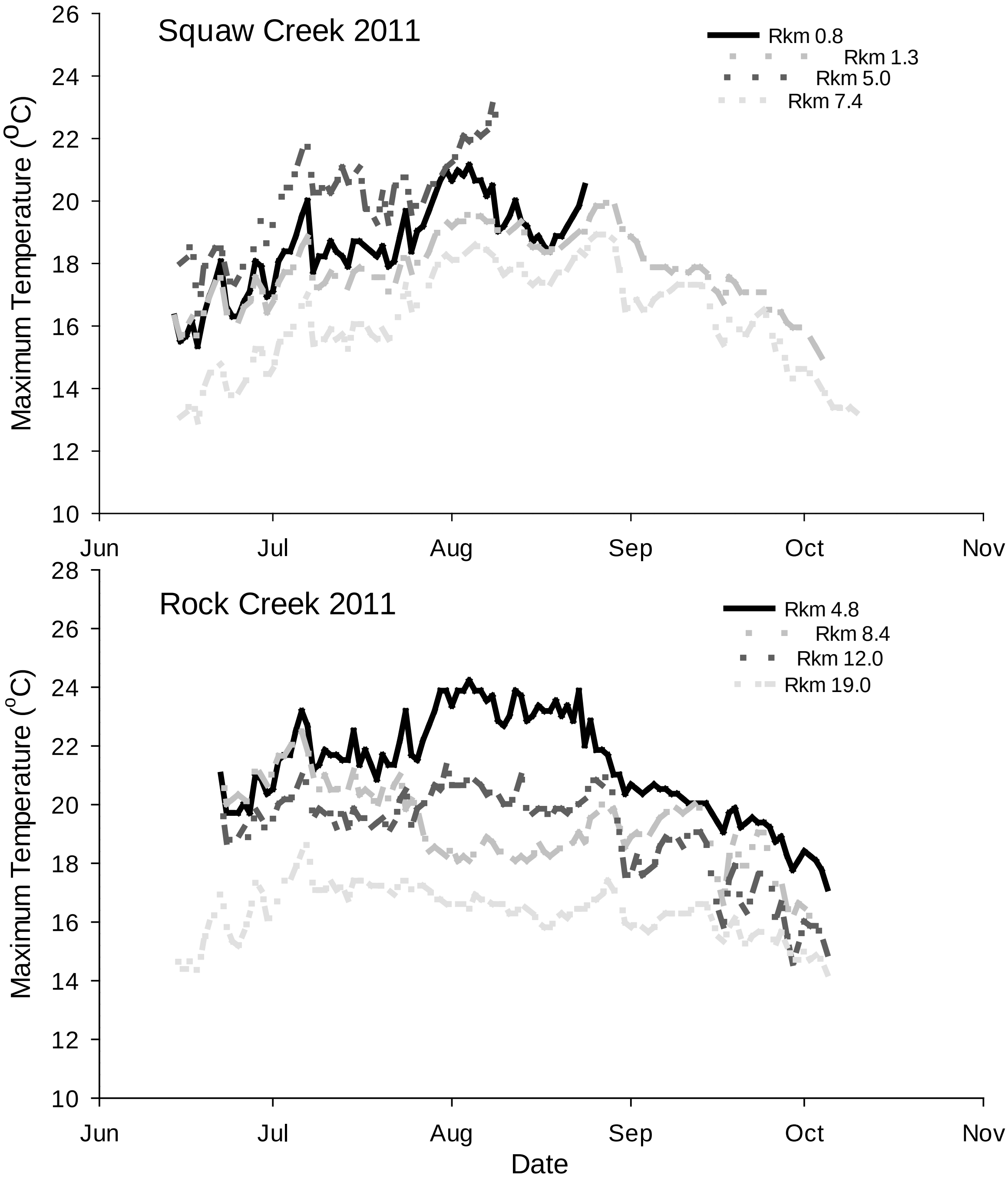


Figure A-9. Representative maximum daily water temperatures in Rock Creek and Squaw Creek, WA during summer 2011. There was a break in the water temperature data for Squaw Creek at rkm 0.8 and 5.0 because the temperature recording device was out of the water during that time period. See Table A-2 for additional temperature information.

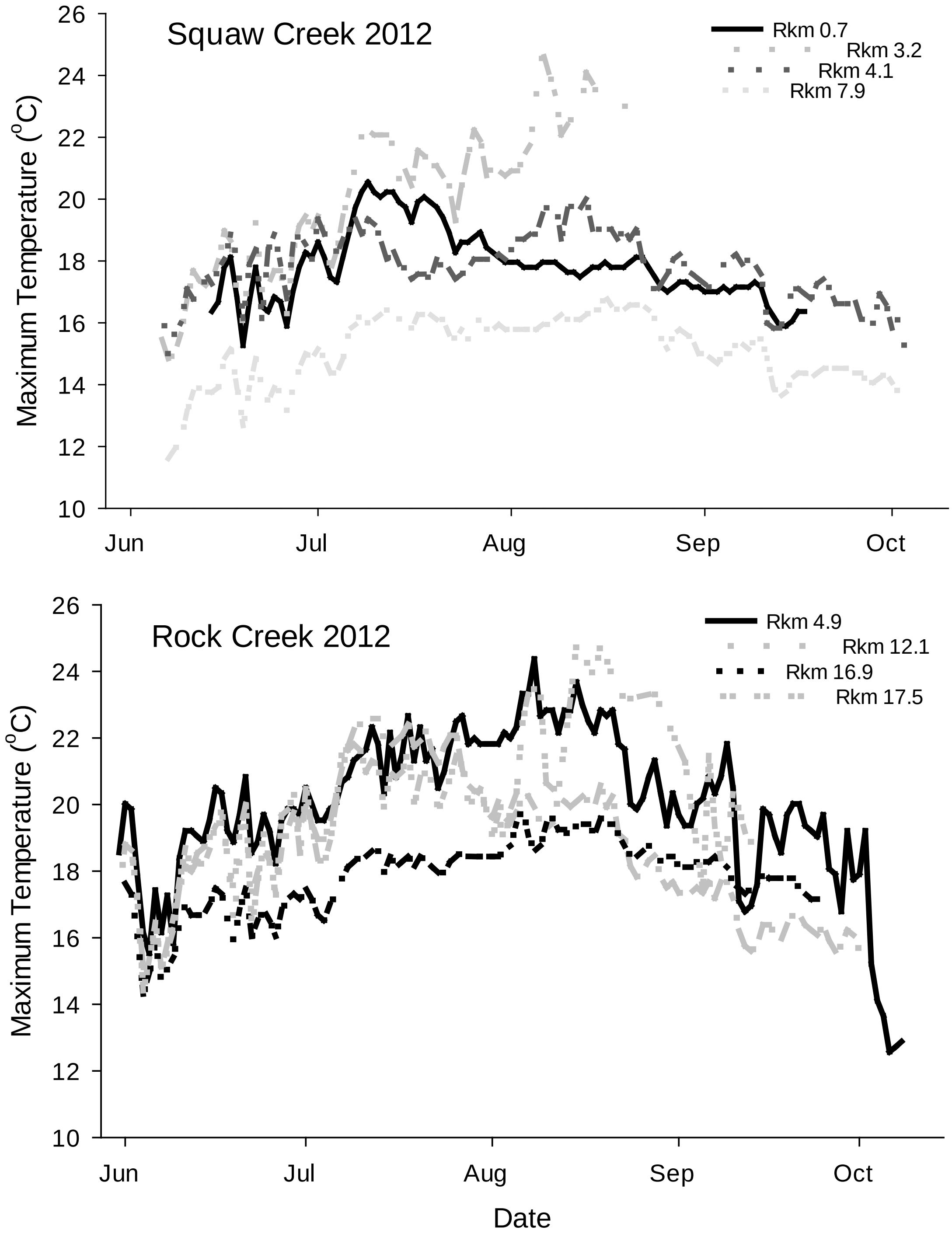


Figure A-10. Representative maximum daily water temperatures in Rock Creek and Squaw Creek, WA during summer 2012. See Table A-2 for additional temperature information.

Table A-2. Number of days per year when maximum water temperature exceeded 16°C and 20°C, and maximum water temperature recorded at locations in Rock Creek, July-September 2010-2012. Data are from Onset Corporation's StowAway and Tidbit temperature loggers. Sites are listed from downstream to upstream. D = pool was dry during maximum temperature period.

	Number of days > 16			Number of days >20			Maximum		
RKM	2010	2011	2012	2010	2011	2012	2010	2011	2012
Rock Creek									
4.8	---	92	91	---	75	66	---	24.2	24.4
8.4	---	92	90	---	26	4	---	22.5	20.4
11	81	---	---	45	---	---	23.8	---	---
12.0	---	88	---	---	34	---	---	21.3	---
12.1	---	---	85	---	---	35	---	---	22.6
13	85	87	---	0	8	---	19.3	---	---
13.6	---	---	D	---	---	D	---	---	D
14.2	86	---	---	18	---	---	T 21.2	---	---
14.7	---	92	86	---	8	28	---	21.3	21.8
15.8	---	83	---	---	8	---	---	20.7	---
16.9	92	---	86	0	---	0	18.2	---	19.9
17.7	---	82	D	---	4	D	---	20.7	D
18.6	D	---	---	D	---	---	D	---	---
18.7	---	D	---	---	D	---	---	D	---
18.8	D	---	---	D	---	---	D	---	---
19.0	---	69	---	---	0	---	---	18.7	---
25.7	29	---	---	0	---	---	19.8	---	---
27.1	36	---	---	0	---	---	18.2	---	---
27.5	38	---	---	0	---	---	18.1	---	---
Squaw Creek									
0.7	---	---	69	---	---	7	---	---	20.6
0.8	D	57	---	D	16	---	D	23.5	---
1.3	62	90	---	0	2	---	19.6	20.0	---
1.8	D	D	---	D	D	---	D	D	---
2.1	59	---	75	0	---	18	18.1	---	21.0
3.2	---	---	D	---	---	D	---	---	D
3.7	---	---	77	---	---	29	---	---	21.5
4.1	---	---	87	---	---	2	---	---	20.0
5.0	---	D	D	---	D	D	---	D	D
6.3	---	D	D	---	D	D	---	19.4	D
7.4	---	67	70	---	0	0	---	18.9	19.7
7.6	59	66	81	1	2	10	20.2	20.1	20.3
7.9	36	---	30	0	---	0	17.9	---	16.9
Quartz Creek									
0	45	---	---	1	---	---	20.2	---	---
0.4	50	---	---	6	---	---	20.8	---	---
0.6	53	---	---	11	---	---	20.9	---	---

In 2010, we deployed seven Hobo Tidbits in Rock Creek near the confluence with Quartz Creek (about rkm 27 of Rock Creek) and in the lower kilometer of Quartz Creek (Table A-2, Figure A-8). This was done in the spring of 2010 during an effort to investigate access into the area to conduct electrofishing surveys. Two Tidbits were placed in pools downstream of the Quartz Creek confluence, two were placed above the confluence, and three were placed in Quartz Creek. While we determined that the access was unsafe for a crew carrying electrofishing and fish sampling equipment, we were able to return in the fall of 2010 to retrieve the temperature recording devices and conduct habitat surveys. One Tidbit at rkm 25.4 was in a pool that went dry, but the others remained in the water (Figure A-8). Maximum water temperatures in this reach exceeded 16°C for 29 to 53 days in the summer, but rarely exceeded 20°C, with Quartz Creek being slightly warmer (Table A-2).

Fish Species Distribution

A total of ten species of fish were found in the Rock Creek basin (Table A-3) during our sampling in 2009 through 2012: steelhead/ rainbow trout (*O. mykiss*), coho salmon (*O. kisutch*), Chinook salmon (*O. tschawytscha*), shorthead sculpin (*Cottus confusus*), speckled dace (*Rhinichthys osculus*), red sided shiner (*Richardsonius balteatus*), bridgelip suckers (*Catostomus columbianus*), northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), and brown bullhead (*Ameiurus nebulosus*). *O. mykiss* were the only fish species found at the uppermost sites where we electrofished, which were Rock Creek at rkm 32 and Quartz Creek at rkm 12. No fish sampling was conducted from rkm 23 to rkm 32 in Rock Creek and no fish sampling was conducted in Quartz Creek except at rkm 12. No larval lamprey were observed when electrofishing anywhere within Rock Creek. If a population of Pacific lamprey (*Entosphenus tridentatus*) were rearing in Rock Creek we should have encountered them during our electrofishing surveys (Dunham et al. 2013).

Northern pikeminnow, smallmouth bass and brown bullheads were found only in the lowermost pools in Rock Creek. Smallmouth bass were present in Rock Creek below rkm 5, but not abundant. No smallmouth bass were ever collected in Squaw Creek. We did not find any smallmouth bass above rkm 5 during any of our sampling efforts in 2009 through 2012. The highest abundance of bass was in the lowest 1 km nearest the impounded reach (rkm 2.4). The lower 2 km of Rock Creek are impounded by John Day Dam and were not sampled. We conducted mark-recapture population estimates of smallmouth bass in the fall of 2012 in the two pools that were sampled where they were present (rkm 2.4 and 4.9) and that information is presented in the population abundance section of this report. Northern pikeminnow were abundant in the lowermost pools sampled (up to rkm 5), and were intermittently present, but rare, with a few individuals collected in pools up to rkm 17.5. Only a few brown bullhead were collected each year, mainly in the lowermost pool sampled at rkm 2.4; however, one individual fish was captured at rkm 17.5 in the fall of 2011 and spring of 2012, it may have been the same fish. In the fall of 2012, this same pool was dry.

Redside shiners and bridgelip suckers were present throughout much of the area sampled (Table A-3). However, their abundance decreased as we sampled farther upstream and they were not collected in every pool. Speckled dace and shorthead sculpin were found in every pool and they were abundant throughout the sampled area. The exception was at the uppermost reaches that were sampled, rkm 32 of Rock Creek and rkm 12.5 of Quartz Creek, where only *O. mykiss* were found. Due to two small waterfalls downstream of rkm 32 in Rock Creek and the close proximity to the headwaters of the Quartz Creek sample site, genetic samples of the *O. mykiss* were and submitted to CRITFC to assess their relatedness to *O. mykiss* from downstream as well as other *O. mykiss* populations.

Table A-3. Presence and absence of fish species found in Rock Creek in 2009-2012. If fish species were present in the reach, but not at every sampling site, then the most upstream river kilometer (rkm) where that species was collected is listed. P = present, A = absent.

	Rock Creek								Squaw Creek			
Species	Rkm 2 to 13				Rkm 13 to 22				Rkm 0-8			
	2009	2010[a]	2011	2012	2009	2010[a]	2011	2012	2009	2010[a]	2011	2012
O. mykiss	P	P	P	P	P	P	P	P	P	P	P	P
Shorthead sculpin	P	P	P	P	P	P	P	P	P	P	P	P
Speckled dace	P	P	P	P	P	P	P	P	P	P	P	P
Redside shiner	P	P	P	P	20	18.5	18.6	17.5	3.2	3.2	0.7	3.7
Bridgelip Sucker	P	P	P	P	16.9	14.7	17.5	20.0	3.2	2.2	2.2	A
Coho salmon	6 [b]	P	P	2.4 [c]	15.3 [b]	13.0	21.6	A	A	4.1	8	3.7 [c]
Chinook salmon	A	A	A	2.4	A	A	A	A	A	A	A	A
Northern Pikeminnow	4.9	A	P	P	A	A	A	17.5 [d]	A	A	A	A
Smallmouth bass	4.9	3	4.9	4.9	A	A	A	A	A	A	A	A
Brown Bullhead	2.4	A	2.4 [e]	2.4 [e]	A	A	17.5 [e]	17.5 [e]	A	A	A	A

[a] Sampling was conducted only in the spring of 2010, no sampling was conducted in the fall of 2010.
[b] Coho were collected only in one pool at rkm 6 and one pool at rkm 15.3 in 2009.
[c] Only 6 coho were collected from 3 pools in 2012 (rkm 2.4 in Rock Creek and rkm1.2 and 3.7 of Squaw Creek).
[d] Only 2 northern pikeminnow were collected in this reach in 2012, one from 17.5, one from 12.2.
[e] A single brown bullhead was collected in one pool at rkm 17.5 in fall 2011 and spring 2012 (it may have been the same fish), all other brown bullhead were collected at one pool at rkm2.4. In the fall of 2012, the pool was 3 small puddles and had dace, sculpin, and shiners.

From late June to October, nearly all perennial pools sampled in Rock and Squaw creeks were isolated, restricting fish movement. In the fall of 2009 and 2012, *O. mykiss* were rare in the sampled pools in Rock Creek downstream of rkm 8. Only 4 individuals were captured in fall 2009 and 5 were captured in fall 2012. In the fall of 2012, no *O. mykiss* were captured in the pools at rkm 2.4 or 4.9, which were electrofished during population estimates, but five *O. mykiss* were collected in a pool at rkm 4.8 indicating that they survived over summer in some pools in this reach. In contrast, in the fall of 2011, 110 *O. mykiss* were collected in these same pools below rkm 8. This may be, in part, due to higher temperatures and predatory fish in the lower 5 km of Rock Creek in 2009 and 2012. Additionally, a flood occurred on March 30, 2012, that scoured the stream bed and likely caused substantial egg and fry mortality. Consequently fewer age-0 *O. mykiss* were present throughout Rock Creek in spring of 2012 when compared to spring of 2010 and 2011. *O. mykiss* were present in most other pools that retained water upstream of rkm 4.9 in the fall of 2012. This indicates that there was substantial variation in salmonid survival in Rock Creek below rkm 8, but less variation between years in the upstream reaches.

Coho salmon distribution and abundance varied greatly between sampling years (Table A-3). In 2009, juvenile coho were present in only 2 of 36 pools sampled (rkm 6.9 and 15.3). Only 8 coho were found compared to 783 *O. mykiss* in 2009. During the spring of 2010, coho were found in 7 of the 28 pools sampled, but were not abundant. We found only 12 individuals compared to over 950 *O. mykiss*. No sampling was conducted in fall 2010. In 2011, coho were found in 40 of the 57 pools sampled throughout Rock and Squaw Creek. Coho were also far more abundant in 2011 than in all other years of the study. We collected 2,002 individuals compared to 3,325 *O. mykiss*. In 2012, coho were again rare, with a total of 6 coho collected from 3 pools one at rkm 2.4 of Rock Creek and the other two were at rkm 1.2 and 3.7 of Squaw Creek (compared to 2,674 *O. mykiss* from 42 pools). Chinook salmon were absent in most years, with two fish captured at rkm 2.4 in 2012. This suggests that in most years Rock Creek does not have viable Chinook salmon population.

Variations in fish distribution could be due to timing of sampling as well as abiotic factors such as flood events or summer water temperature and availability. In the pilot year (2009), we electrofished in the fall from September 24 to November 5. Our sampling in 2010 only occurred in the spring from May 25 to June 17. In 2011 and 2012, we were able to complete the sampling as it was intended in 2010, with late May through June indexing of fish distribution and mid-September through October population estimates and indexing of fish distribution to assess over summer survival of the species that were encountered.

Fish Abundance

Salmonid abundance estimates were completed in the fall of 2011 and 2012. Pools greater than 120 cm maximum depth were not sampled for safety reasons, and pools less than 70 cm deep were not sampled in the spring to lessen the likelihood that the pool would be dry in the fall. Even with these constraints, the maximum and mean depth of pools that were randomly selected to sample for salmonid population estimates were similar to the other pools in Rock Creek (Figure A-11) and Squaw Creek (Figure A-12). The 2011 and 2012 abundance estimates varied between pools and between years in Rock Creek (Figure A-13) and Squaw Creek (Figure A-14). Several pools in both Rock and Squaw creeks were sampled in the spring (and *O. mykiss* were collected), with the intention of returning in the fall to conduct population estimates. However, when we returned in the fall these pools had either dried out completely, or shrunk to the point that only a few age-0 dace were present. Other pools had essentially the same water depth as in the spring. The overall abundance of age-1 and older *O. mykiss* was higher in 2011 (with an average among pools of 0.63 fish per m^2) than in 2012 (with an average among pools of 0.37 fish per m^2). The overall abundance of age-0 *O. mykiss* was also higher in 2011 (with an average among pools of 1.45 fish per m^2) than 2012 (with an average among pools of 1.03 fish per m^2).

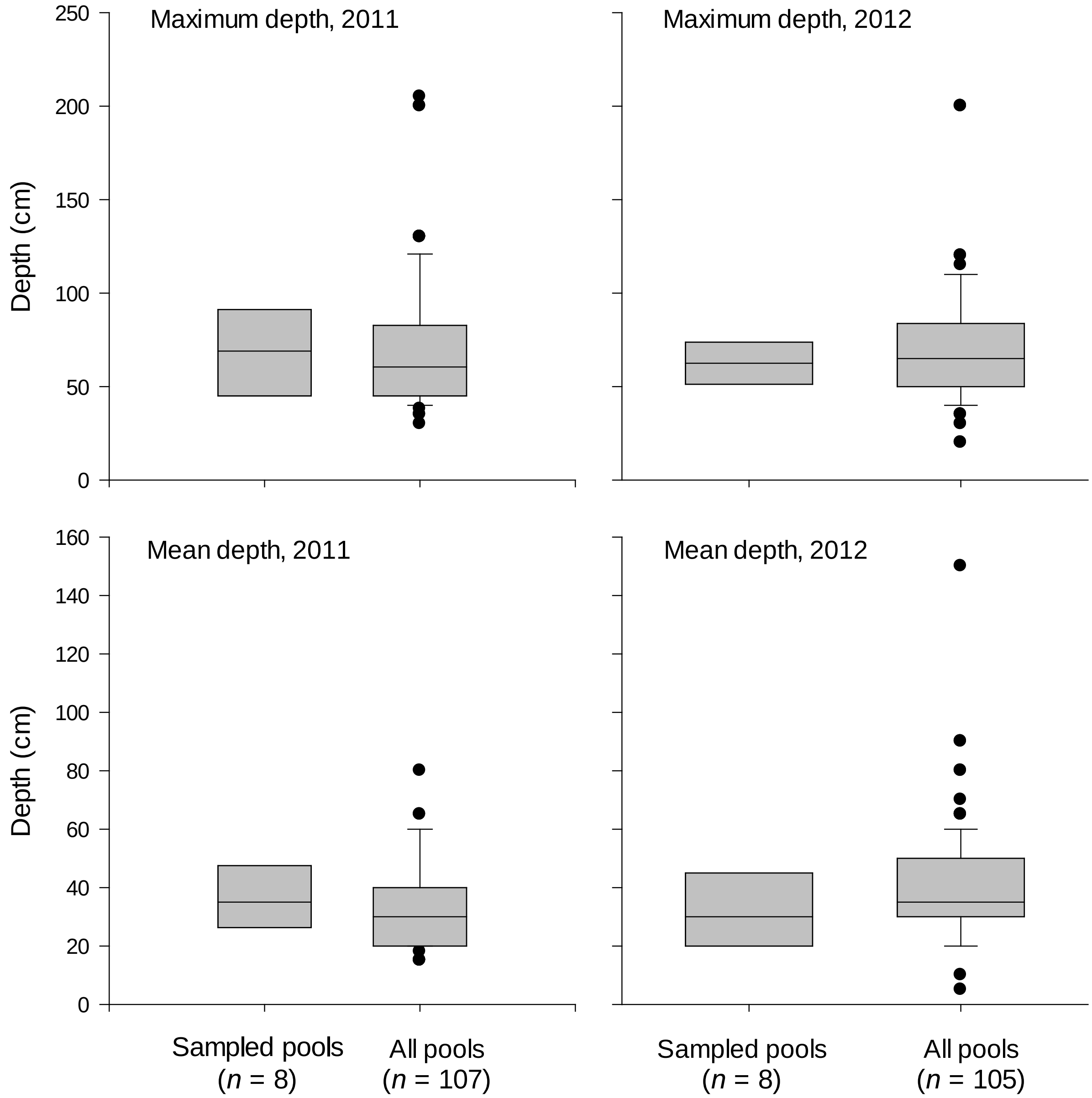


Figure A-11. Maximum and mean depth of pools sampled for fish population estimates compared to all pools within river kilometer 0 to 21 of Rock Creek, WA.

Squaw Creek

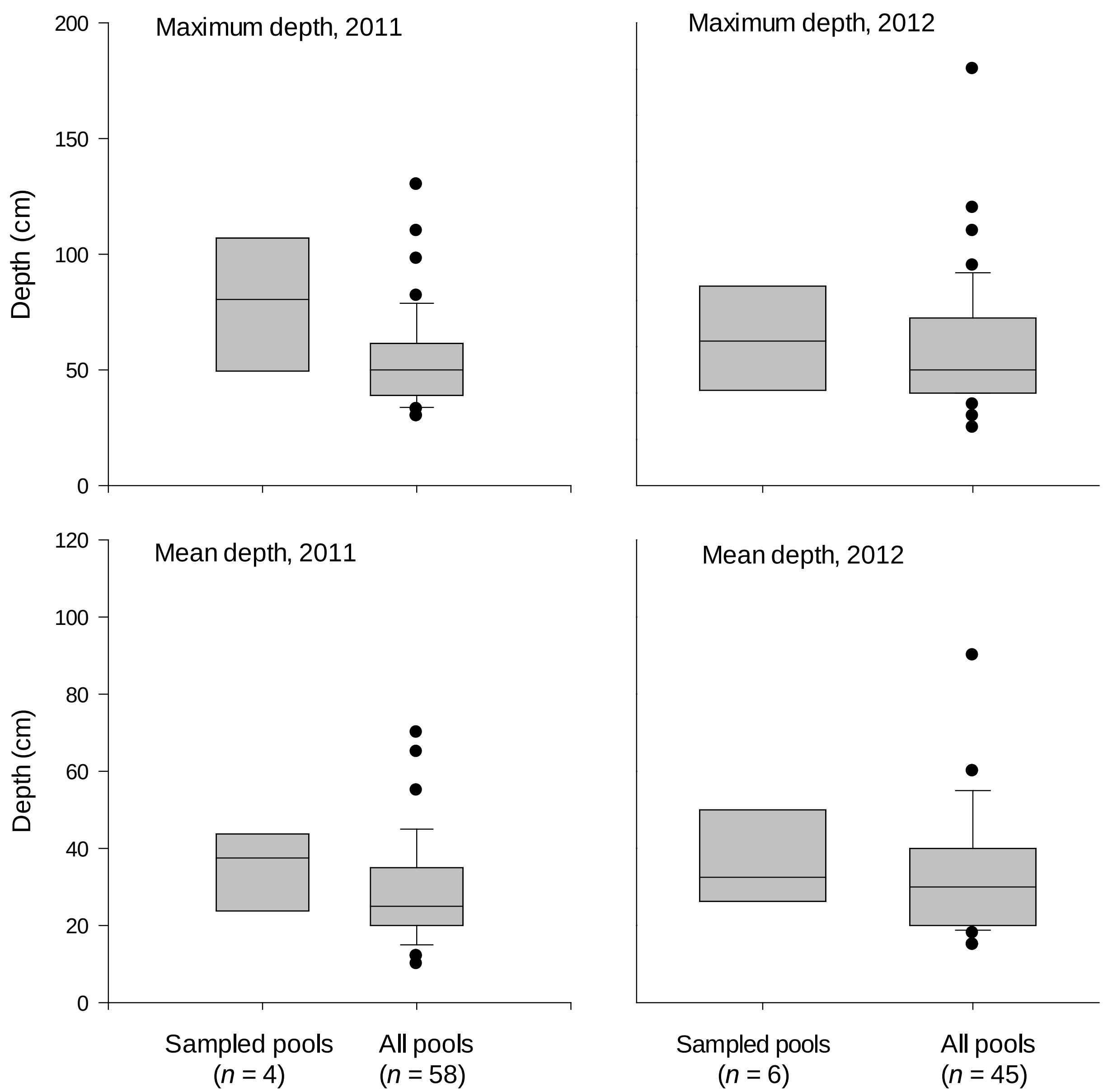
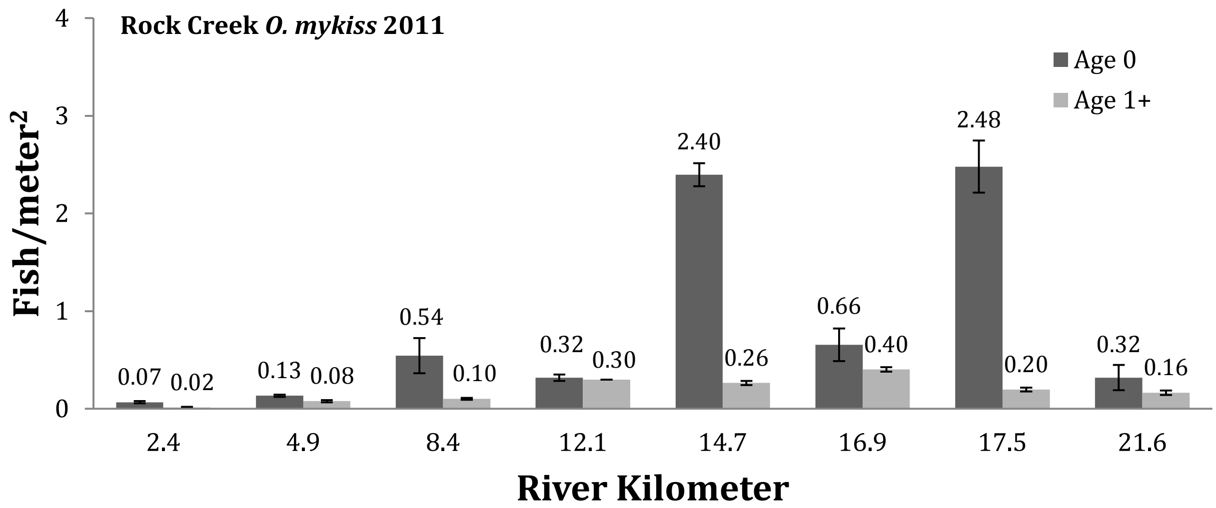


Figure A-12. Maximum and mean depth of pools sampled for fish population estimates compared to all pools within river kilometer 0 to 8 of Squaw Creek, WA.



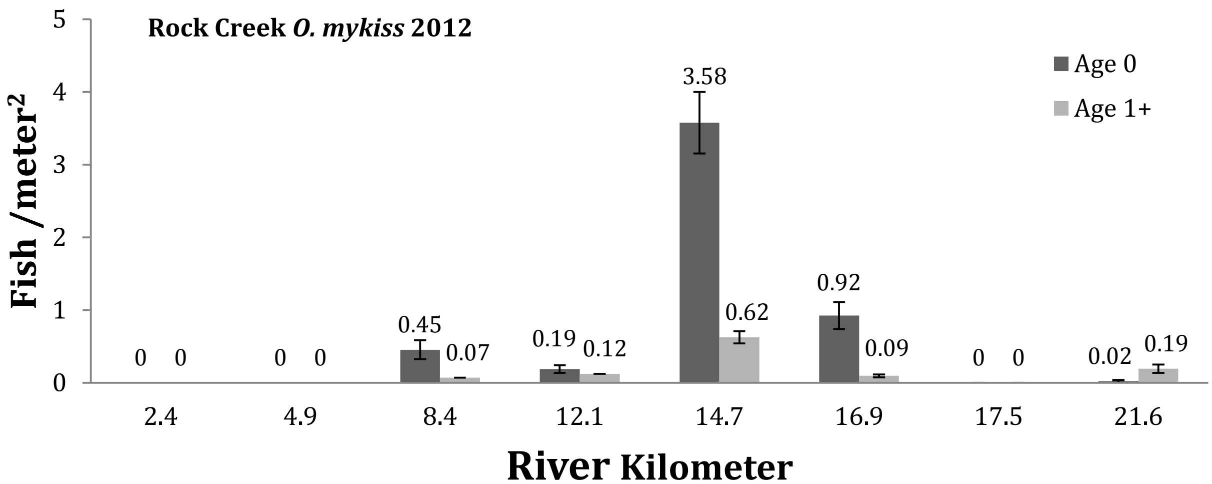


Figure A-13. The number of age 0 (fork length less than 95 mm) and age 1 and older (fork length greater than 95 mm) *O. mykiss* per meter^2 in randomly selected pools of Rock Creek, Washington during fall of 2011 and 2012. Error bars indicate 95 percent confidence intervals of the estimate. No *O. mykiss* were captured in the pools at river kilometer 2.4 and 4.9 of Rock Creek in the fall of 2011, although other fish species were present.

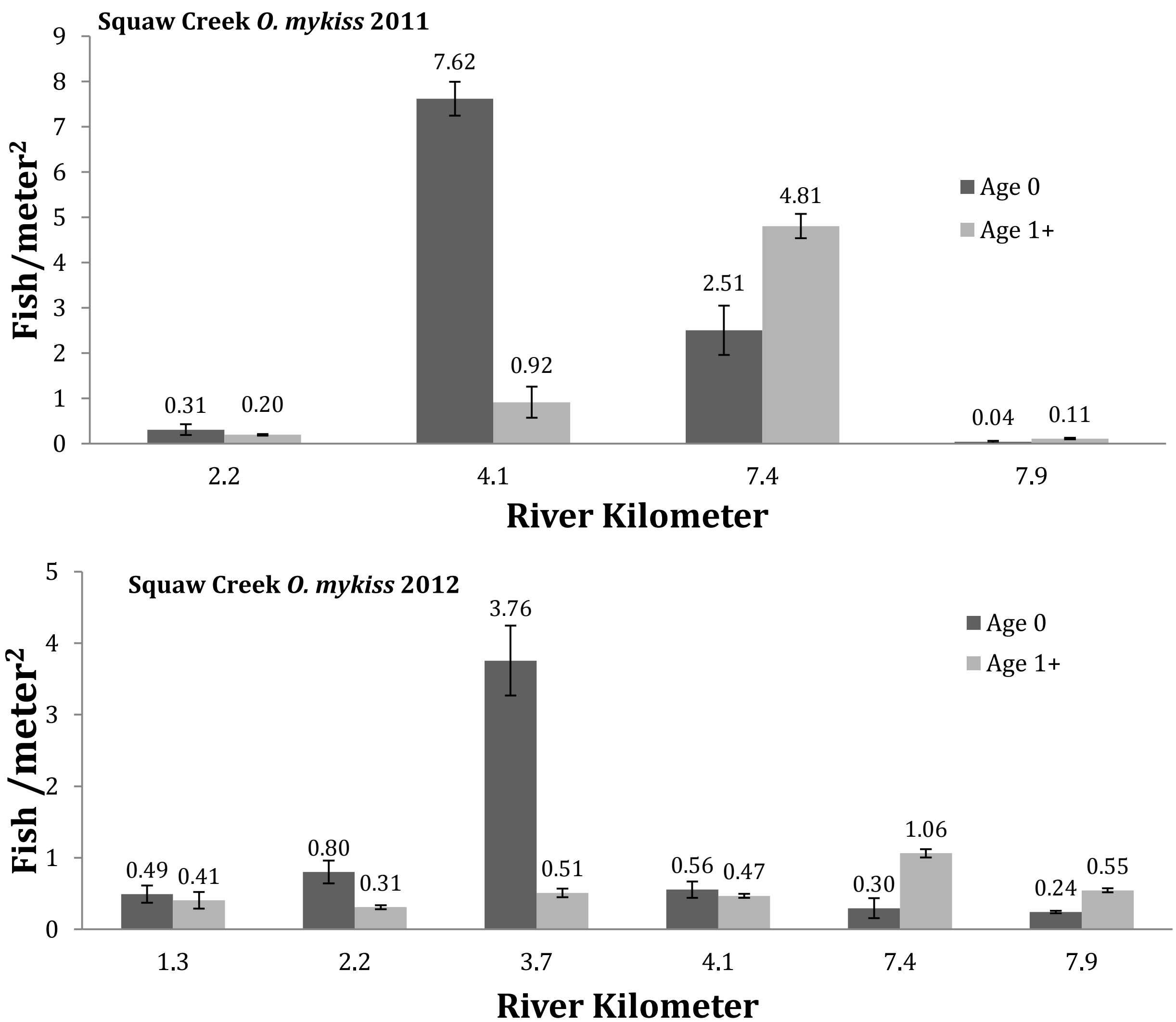
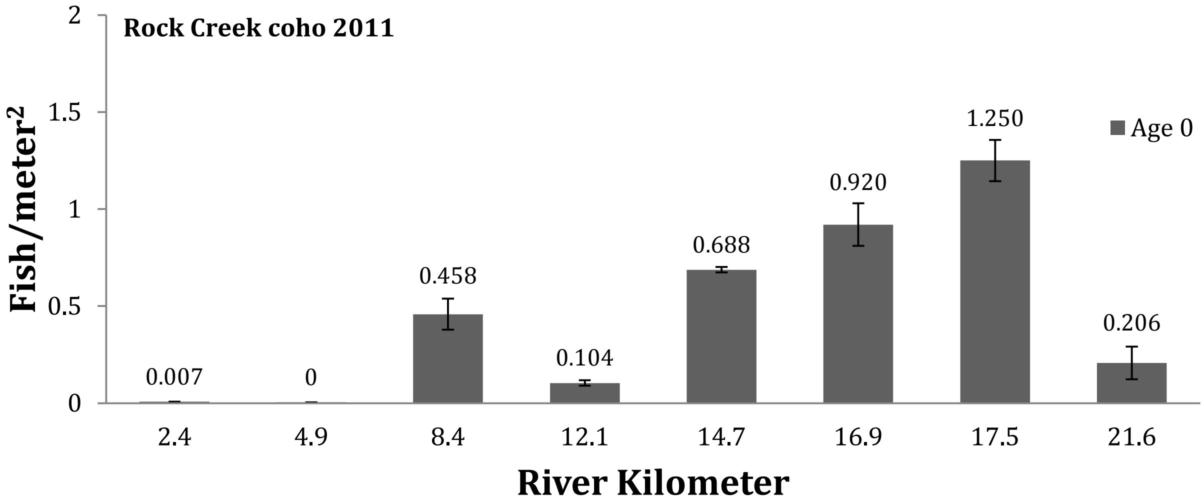


Figure A-14. The number of age 0 (fork length less than 95 mm) and age 1 and older (fork length greater than 95 mm) *O. mykiss* per meter^2 in randomly selected pools of Squaw Creek, Washington during fall of 2011 and 2012. Error bars indicate 95 percent confidence intervals of the estimate.

Coho were abundant in 2011, but not in 2010 or 2012. Population estimates for coho were conducted in the same pools as for O. *mykiss* (Figure A-15). Coho abundance was similar to that of *O. mykiss* in 2011 with an overall abundance of 1.1 age-0 fish per m2. No age-1 or older coho were collected.



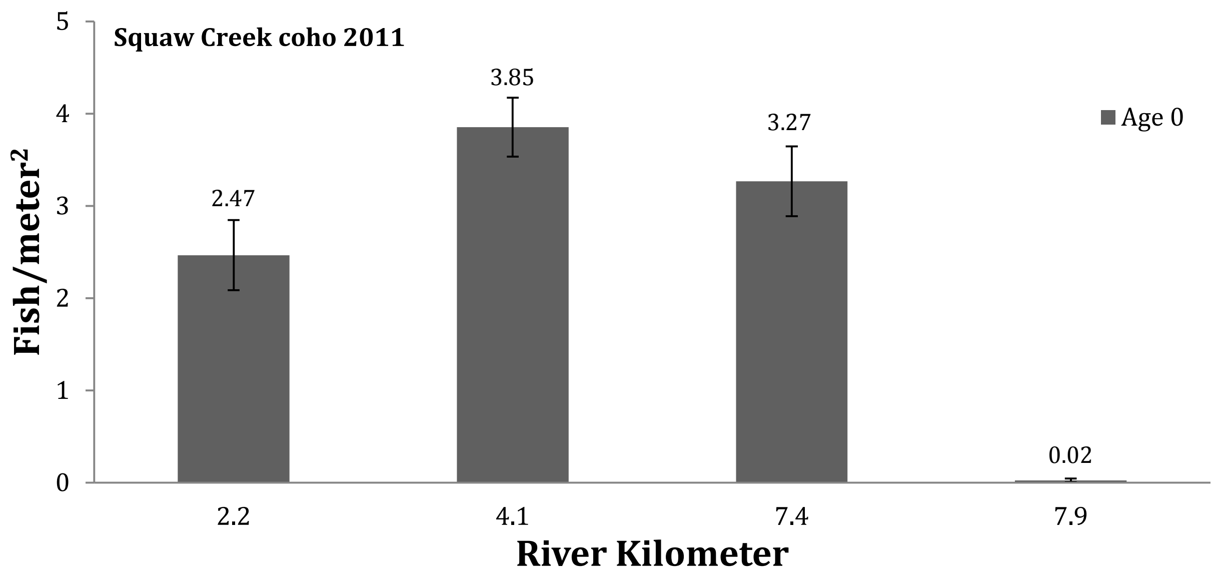


Figure A-15. The number of age coho per meter^2 in randomly selected pools of Rock and Squaw Creek, Washington during fall of 2011. Error bars indicate 95 percent confidence intervals of the estimate. No coho were captured at river kilometer 4.9 in Rock Creek, although other fish species were present including *O. mykiss*.

Age-0 *O. mykiss* presence and abundance in the spring (May and June) varied between sites and sampling years, particularly downstream of rkm 12. Age-0 *O. mykiss* were rare downstream of the Squaw Creek confluence in the fall of 2009, but abundant in all other sampled pools in 2009. In the spring of 2010 and 2011, age-0 O. *mykiss* were found in high abundance in every pool that was sampled. In the spring of 2012, age-0 *O. mykiss* were less abundant than in other years, based on visual estimates of abundance. This was likely due to the flood event that occurred in March of 2012. However, by fall of 2012, the age-0 *O. mykiss* abundance was not notably different than in 2011. This suggests that compensatory mortality may occur in Rock Creek over the summer as the available habitat shrinks with decreasing water availability. Therefore, carrying capacity of perennial pools limits overall *O. mykiss* abundance.

In addition to salmonid population abundance estimates, smallmouth bass and northern pikeminnow abundance estimates were completed in the fall of 2012. Estimates were 0.8 smallmouth bass per m^2 (S.E. 0.2) and 0.4 smallmouth bass per m^2 (S.E. 0.1) in the two pools (rkm 2.4 and rkm 4.9) where smallmouth bass were found. The bass were mostly age 0, with a median fork length of 85 mm. Only four smallmouth bass were collected with fork lengths greater than 100 mm (185 mm, 168 mm, 138 mm, and 137 mm). Northern pikeminnow were present and abundance was estimated at rkm 2.4, where there were 0.9 fish per m^2 (S.E. 0.2). The median fork length of northern pikeminnow was 117 mm (min. 76 mm and max. 170 mm). Northern pikeminnow and smallmouth bass were not found in other pools farther upstream in Rock Creek. Given the limited distribution within the watershed and the small size of these piscivores, it is unlikely that they are a major source of mortality for salmonids in Rock Creek upstream of the inundated reach (rkm 2). The fish population was not assessed within the inundated reach, but fish species composition, abundance, and size are likely different from the rest of the Rock Creek drainage basin and more likely resemble that of the mainstem Columba River.

Salmonid Growth

Analysis of length-frequency histograms of *O. mykiss* sampled in the spring and fall of 2011 and 2012 showed the change in FL of the population over that time period, with the change in length of the age-0 fish being the most evident (Figures A-16 and A-17). Because of the variability in the growth of fish over time, it becomes much more difficult to identify age classes of age-1 and older fish. The overall height of individual bars in the histograms (Figures 16 and 17) were an artifact of our selective collection of fish during electrofishing, which was done to reduce the overall number of *O. mykiss* that were handled. In the spring, all age-1 salmonids that were encountered were captured (for PIT-tagging), but we intentionally handled only a representative subset of the age-0 fish in any pool (typically 15 fish). Whereas, in the fall a much higher proportion of the age-0 fish were handled and measured in some pools as part of the mark-recapture methodology (all age-0 and age-1 fish that were easily captured were handled). Therefore, the height of the individual bars in the histogram were skewed lower for age-0 fish (FL between 25 and 80 mm) in the spring because of this size-based difference in collection effort. In the fall, the height of the bars in the histogram more accurately represented the abundance of the age class. However, the shape of the length-frequency histograms does illustrate the typical change in fork length of the age-0 cohort, and the length that separated the age-0 and age-1 *O. mykiss*. By looking at the highest bar within each season of fish that were 25 to 90 mm, we estimated that age-0 fish grew about 25 to 30 mm from spring to fall in both Rock and Squaw creeks. In the fall of 2009, 2011, and 2012, the break in FL between age-0 and age-1 fish was estimated to be about 95 mm. The fork length of age-0 *O. mykiss* captured upstream of the Squaw Creek confluence (rkm 13 to 21) was slightly smaller than fish captured downstream of the confluence (rkm 2 to 13) in the fall of 2011 (Figure A-18). The increased fork length seemed to follow the cohort into the next year, with larger age-1 and older *O. mykiss* captured downstream of the Squaw Creek confluence. However, the age-0 *O. mykiss* captured in 2012 appeared to be essentially the same size regardless of capture location in Rock Creek (Figure A-18).

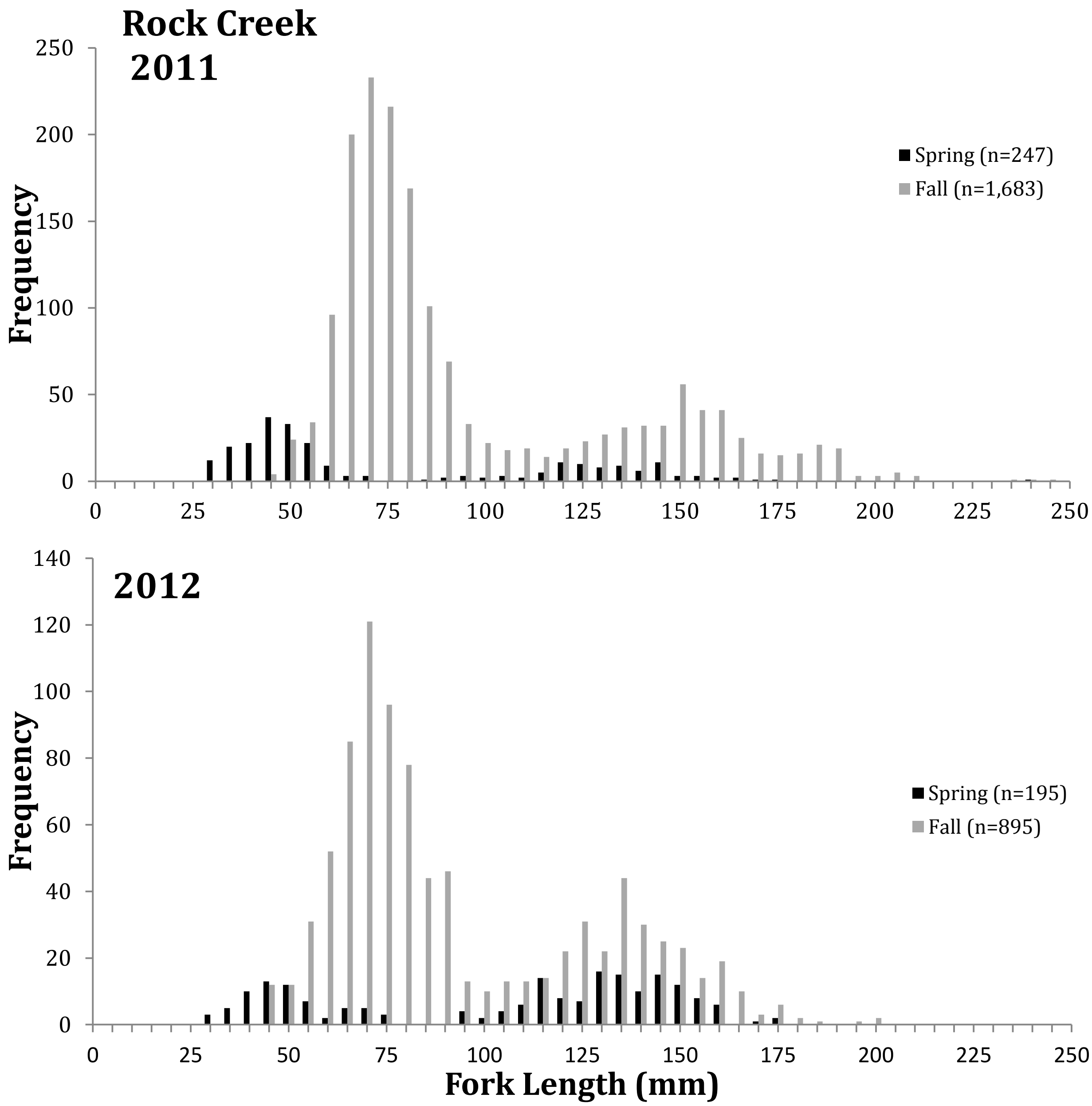


Figure A-16. Length frequency histograms of *O. mykiss* sampled in Rock Creek in spring and fall of 2011 and 2012.

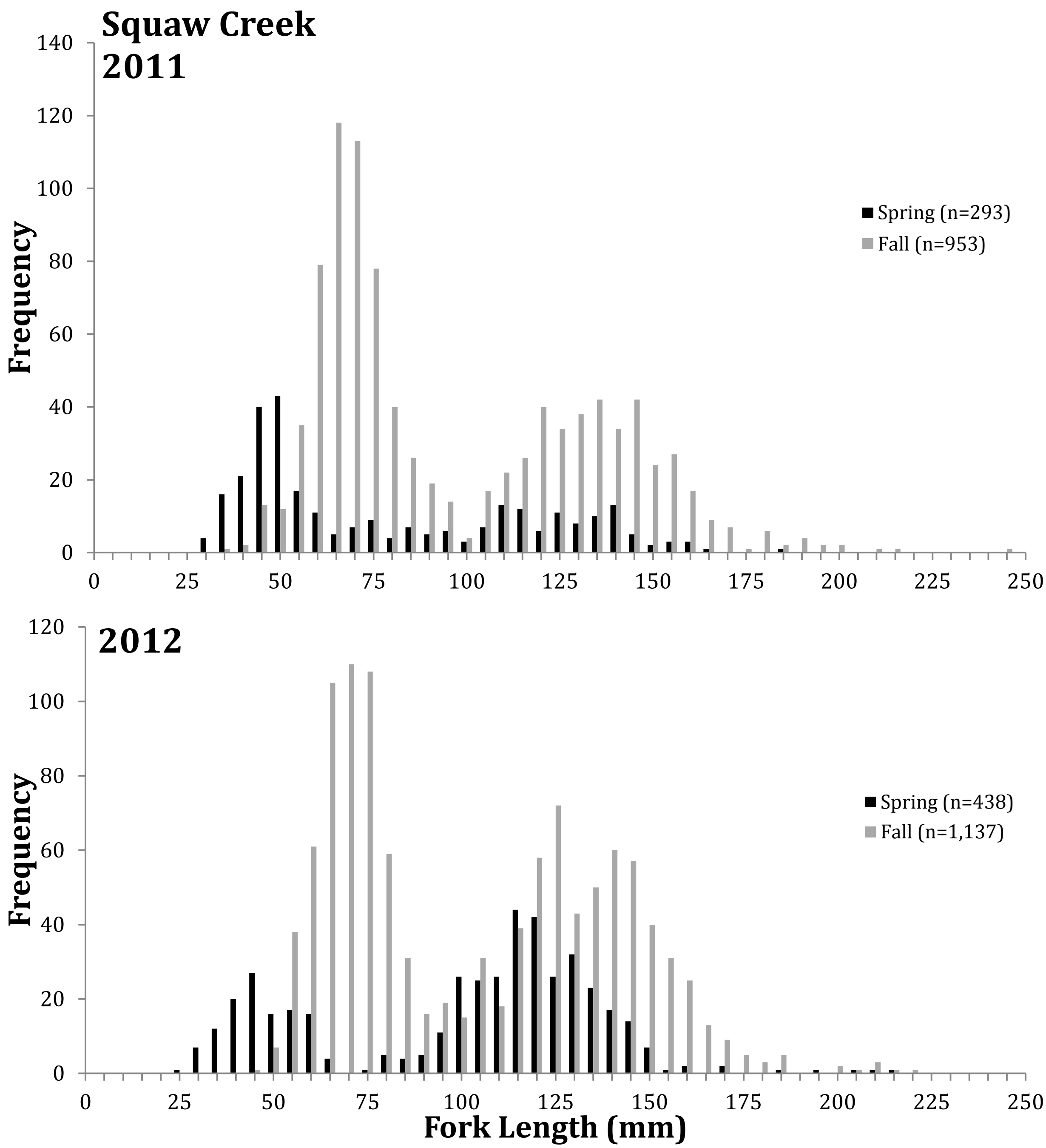


Figure A-17. Length frequency histograms of *O. mykiss* sampled in Squaw Creek during spring and fall of 2011 and 2012.

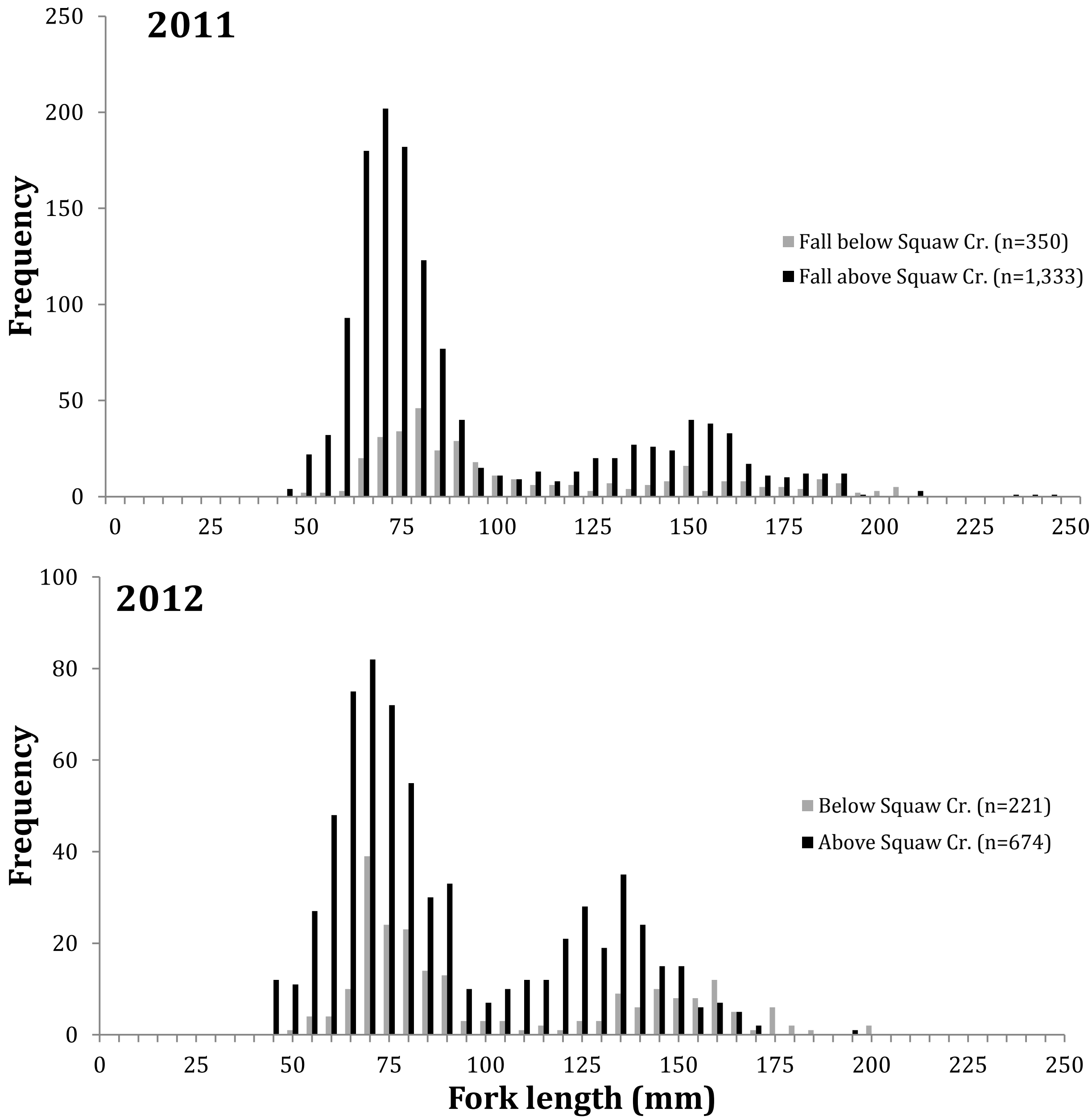


Figure A-18. Length frequency histograms of *O. mykiss* captured in Rock Creek upstream (above) and downstream (below) of the Squaw Creek confluence (at river kilometer 13) in the fall of 2011 and 2012.

In a few of the larger and deeper pools, some of the *O. mykiss* were very likely to be resident rainbow trout. These fish had more red coloration along the lateral line and cheeks, they were larger (FL greater than 185 mm), and had body shapes that were deeper bodied than other *O. mykiss* that were handled in the same locations. Not many of these fish were handled (about 15 per year); however, this life history was likely to be present in Rock Creek, and younger resident rainbow trout would look similar to the anadromous *O. mykiss* parr. Therefore, the composition of anadromous versus resident life histories was unknown, other than for the individual PIT-tagged fish that were detected outmigrating.

There was only one age class of coho present in any significant number in Rock and Squaw creeks (Figure A-19). Nearly all of the coho in Rock Creek were age-0 fish captured in 2011. The coho were too small to PIT tag in the spring of 2011 to gain information on individual fish growth or movement. However, the length-frequency histogram indicated that the age-0 coho grew about 15 to 20 mm from June to September/October in 2011. The pools were isolated when sampling was conducted in the spring. This habitat disconnection continued through the fall sampling period.

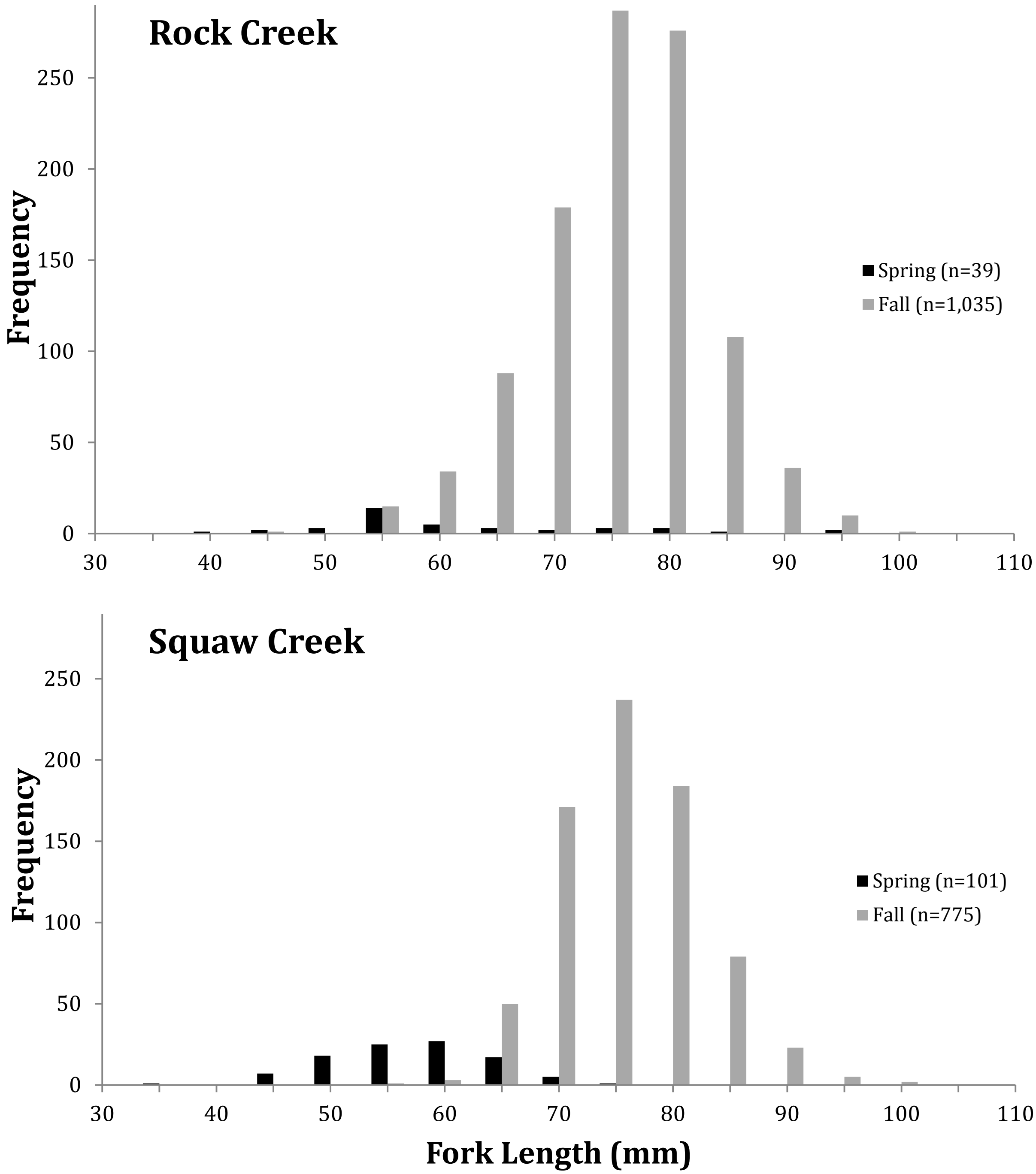


Figure A-19. Length frequency histogram of coho salmon sampled in Rock and Squaw creeks in 2011.

Marking *O. mykiss* with PIT tags provided the ability to measure the change in FL of individual recaptured fish. However, age-0 fish were typically too small to PIT tag until the fall sampling period when the larger fish in the age-0 cohort were able to be tagged. So, the growth of PIT-tagged fish was largely applicable to age-1 and older fish. Age-1 *O. mykiss* had an average annual growth rate of 56 mm from fall 2011 to fall 2012 (n = 11, min = 35 mm, max = 73 mm). However, too few fish were recaptured between years to determine differences in growth based on tagging location or year. The sample size of fish tagged and recaptured within the same year was much greater. A total of 31 age-1 *O. mykiss* tagged in spring (June) 2011 were recaptured in the fall (September and October) in 2011. In 2012, 116 age-1 *O. mykiss* tagged in spring were recaptured that fall (Table A-4). The number of days between tagging and recapture ranged from 100 to 124. Mean growth in FL of *O. mykiss* during that time period ranged from 6 mm in Squaw Creek in 2012 to 12 mm in Rock Creek above Squaw Creek in 2011 (Table A-4). Ten *O. mykiss* shortened in FL by 1 to 3 mm, but over 90% of the fish increased in fork length during that time period. It should be noted, however, that 1 to 3 mm is well within the range of measurement error when measuring fish lengths (Bunch et al 2013). The maximum growth of an individual *O. mykiss* was 55 mm (from 127 mm in June to 182 mm in October over 133 days) in Squaw Creek in 2012. Only two fish were recaptured in Rock Creek downstream of Squaw Creek from 2011 through 2012. These over-summer growth rates indicate that, even during the season when the pools are isolated and water temperatures were at their maximum, requiring high metabolic activity, conditions for the majority of fish were such that growth occurred.

Table A-4. The number, growth (mm) in fork length (FL), the number of days between capture and recapture and the initial FL of *O. mykiss* that were marked in June and recaptured in September or October in Rock Creek, Washington during 2011 and 2012.

	Reach:	Squaw		Rock below Squaw		Rock above Squaw	
	Year:	2011	2012	2011	2012	2011	2012
Metric	River kilometer:	0-8	0-8	0-13	0-13	14-22	14-22
Number of recaptured fish		26	97	0	2	5	17
Average growth (mm)		8	6	--	11	12	7
Standard error		1	1	--	7	3	1
Minimum growth (mm)		-2	-3	--	4	6	-2
Maximum growth (mm)		25	55	--	17	21	17
Average days between capture		125	124	--	124	117	118
Minimum days between capture		100	117	--	124	109	116
Maximum days between capture		129	133	--	124	125	120
Average initial FL (mm)		119	119	--	144	139	125
Minimum initial FL (mm)		91	80	--	142	122	100
Maximum initial FL (mm)		141	160	--	146	170	146

Fish Diseases

In general, fish collected in Rock Creek and its tributaries were in good health. From fall of 2009 to fall of 2012, a total of 207 fish were submitted to the LCRFHC. These samples included 120 *O. mykiss*, 27 coho, and 60 speckled dace. While most of the fish were in good health, some fish diseases were detected. Parasites and diseases that were commonly observed in the field included: Neascus or blackspot (*Uvulifer ambloplitis*), copepods (*Salmincola californiensis*), and symptoms common to bacterial kidney disease (*Renibacterium salmoninarum*). These parasites were also confirmed by the LCRFHC. Other less common parasites and diseases that were detected by the LCRFHC include: *Nanophyetus salmincola*, unidentified digenetic trematodes, *Epistylis sp*., and *Henneguya salminicola*. Although diseases were detected in some fish, 165 (80%) of the fish submitted to LCRFHC appeared to be in good health with no parasites or diseases found.

Salmonid Movement

During electrofishing surveys, we PIT tagged 3,088 *O. mykiss* and 151 coho (Tables A-5 and A-6). A total of 832 *O. mykiss* (27%) and 57 coho (38%) were detected moving across a PTIS in either Rock Creek or the Columbia River. Only 6 (8%) of the 77 PIT-tagged *O. mykiss* with fork lengths greater than 185 mm were detected at these sites, suggesting that most of these larger fish have a resident life history. Juvenile PIT-tagged fish were typically detected moving during the descending limb of the hydrograph as the water warmed, with 92% (*n*=695) passing RCL in April and May (Figure A-20). Eleven percent (*n*=67) of the PIT tagged fish detected passing RCS moved downstream in the winter to rear between RCS and RCL. A small proportion (2%, n=17) of PIT-tagged fish moved downstream of RCL during the winter (November through February), but it is unknown whether they remained in Rock Creek below rkm 5 or migrated to the Columbia River during this time, as the hydropower juvenile bypass systems where they might have been detected typically do not operate in the winter (from November 30 to March 31). There was little evidence that the migration date of fish was related to tagging location (Figure A-21). Fish migrated downstream during the same period regardless of the river kilometer where they were tagged. The exception to this was for fish that were tagged within a few kilometers of the PTISs (Figure A-21). These fish were detected during the winter at the PTISs; however, they were likely moving to nearby habitat to rear as most of the fish detected in the winter at RCS did not migrate past RCL until spring.

Table A-5. The total number of *O. mykiss* handled and PIT-tagged in Rock Creek and its tributaries from 2009 through 2012, as well as the number of fish detected at PIT-tag interrogation systems in Rock Creek, which is a tributary of the Columbia River at rkm 368 with two sites, RCS at river kilometer (rkm) 13 and RCL (rkm 5) and the Columbia River. Downstream detection sites in the Columbia River were JDJ (John Day Dam juvenile bypass at rkm 347), B2J (Bonneville Dam juvenile bypass at rkm 234), BCC (Bonneville Dam corner collector at rkm 234), TWX (PIT tag detection trawl operated at the Columbia River estuary at rkm75), ESANIS (East Sand Island bird colony at rkm 7). Adult ladder detection sites in the Columbia River were BON (Bonneville Dam adult fish passage ladders at rkm 234), TD1 (The Dalles Dam adult fish passage ladders at rkm 308), and MCN (McNary Dam adult fish passage ladders at rkm 470). Detection information was last updated 11/15/2013.

Stream:	Rock								Squaw				Luna	
Year:	2009		2010		2011		2012		2009	2010	2011	2012	2011	
Rkm:	0-13	13-22	0-13	13-22	0-13	13-22	0-13	13-22	0-8	0-8	0-8	0-8	0	Grand Total
Number handled	4	451	212	329	451	1611	265	828	327	420	1,256	1,606	7	7,820
Number tagged	3	299	7	21	158	561	136	385	249	69	453	691	7	3,088
Number detected	0	105	3	5	41	102	48	163	92	18	102	152	1	832
Number of individual fish detected at individual interrogation sites														
RCS		92	3	1	4	60	6	156	93	15	61	139	1	630
RCL		91		3	33	84	43	148	87	11	75	138	1	714
JDJ		28		1	10	37	12	41	30	8	25	39		231
B2J		8			1		4	8	1			11		33
BCC		15			1	2	8	9	15	2	3	10		65
TWX		2			1	1		2	2			3		11
ESANIS		12	1		3	2			4	1	2			25
BON		2			1	2			2	2	1			9
TD1		1			1	2				2				6
MCN		2			1	1				1				5

Table A-6. The total number of coho handled and PIT-tagged in Rock and Squaw creeks from 2009 through 2012 as well as the number of fish detected at PIT-tag interrogation systems in Rock Creek, RCS at river kilometer (rkm) 13 and RCL (rkm 5)) and the Columbia River. Downstream detection sites in the Columbia River were JDJ (John Day Dam juvenile bypass at rkm 347), B2J (Bonneville Dam juvenile bypass at rkm 234), and the BCC (Bonneville Dam corner collector at rkm 234). Detection information was last updated 11/15/2013.

Stream:	Rock				Squaw			
Year:	2010	2011		2012	2010	2011	2012	
Rkm:	0-13	0-13	13-21	0-2	0-4	0-8	0-3	Grand Total
Number handled	7	235	907	3	5	860	3	2,020
Number tagged	0	25	26	2	5	92	1	151
Number detected	0	6	9	1	1	40	0	57
Number of detections at individual interrogation sites								
RCS		2	5			8		15
RCL		6	9		1	32		48
JDJ		1	2			10		13
B2J						2		2
BCC		1		1		2		4
BON			2			1	1	4
TD1			2			1	1	4

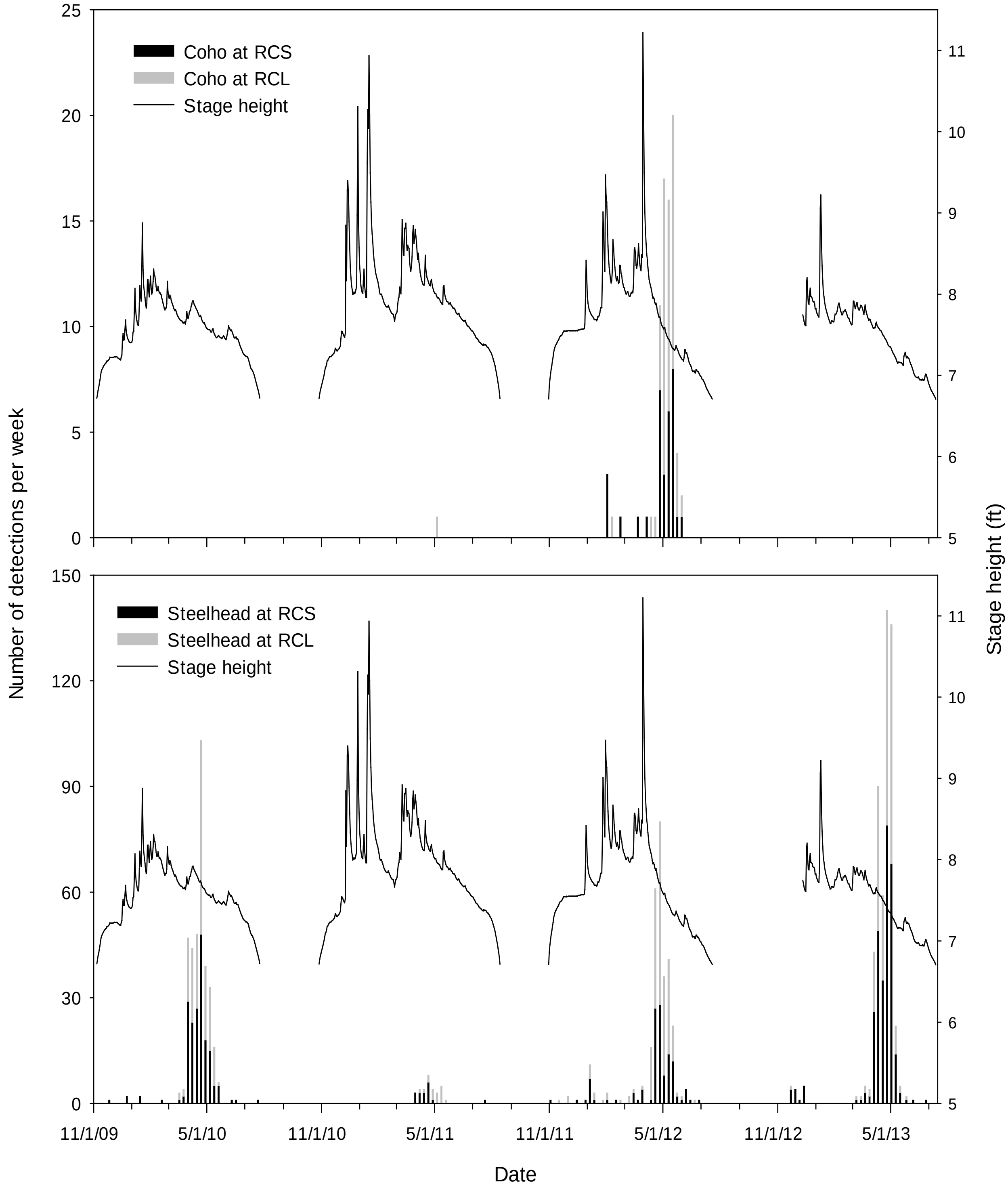


Figure A-20. The number per week of coho and *O. mykiss* that were detected passing the PIT-tag interrogation systems at RCS (rkm 13) and RCL (rkm 5) in Rock Creek from November 2009 to July 2013.

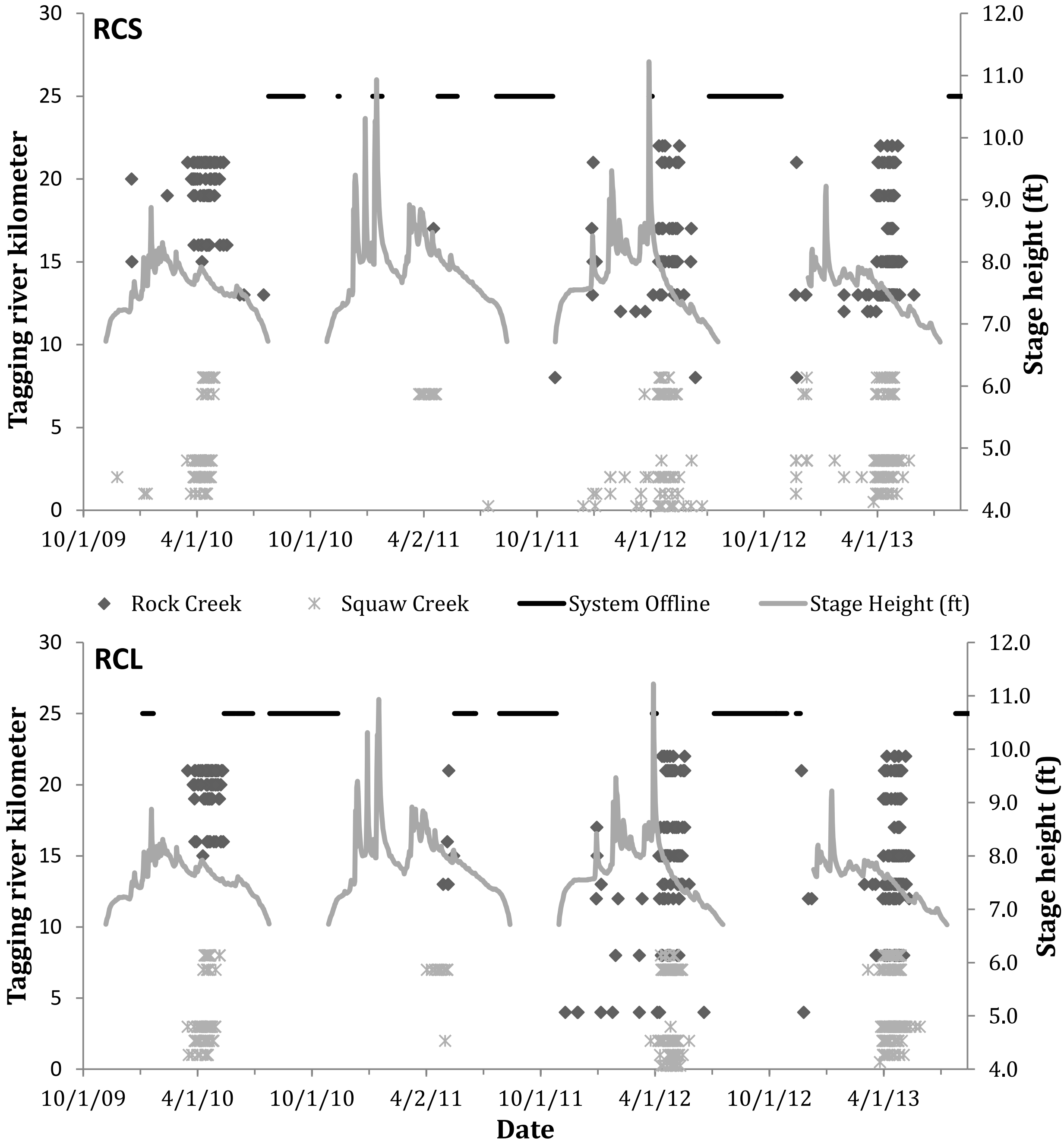


Figure A-21. Date of detection of PIT-tagged *O. mykiss* at Rock Creek at the Squaw Creek confluence (RCS) at river kilometer (rkm) 13 and Rock Creek near the longhouse (RCL) at rkm 5 based on the river kilometer where they were tagged and Rock Creek discharge (stage height). The line across the top of each graph indicates when the PIT-tag detection systems were offline due to flood, system malfunction, or removal during the time when there is no surface water flow.

Very few (*n*=8) of the 172 PIT-tagged fish that were recaptured when electrofishing were in a pool that was different from where they were tagged. This was expected, as the majority of recaptured fish were tagged in the spring and recaptured in the fall (*n*=148), during a time when the riffles were typically dry or nearly dry. Of the 23 PIT-tagged fish that were recaptured with at least 237 days between tagging and recapture (which included winter when flow would have allowed for movement), only one fish was recaptured in a different pool from where it was tagged. This fish was likely a resident *O. mykiss* (155 mm when tagged and 208 mm when recaptured) and had moved about 1 km upstream into a larger and deeper pool. However, fish that migrated into one of the many unsampled pools would not have been recaptured and those that outmigrated as smolts were typically not recaptured. Also, longer distance movements of fish during the winter and early spring would not have been detected if they then returned to the same pool where they were tagged. An exception to this would have been if that movement took them across one of the PTISs and we had no PTIS detections as evidence of this type of movement.

Of the 521 juvenile *O. mykiss* that were detected at both RCS and RCL, it took them a median of 0.9 days and a mean of 4.9 days to travel from RCS to RCL (Figure A-22). However 12 fish took between 70 and 157 days to travel the 9 km between these interrogation sites, suggesting that juvenile *O. mykiss* rearing does occur in the winter/spring for a few fish in this reach until the out-migration period. Some fish also reared near the interrogation sites (mostly RCS), with 53 *O. mykiss* spending at least a day at RCS and one fish spending 146 days at the site (this does not include fish tagged within 1 km of RCS). Coho travel times were similar to those of *O. mykiss* (Figure A-22). Of the 26 coho detected at RCS and RCL, they took a median of 1.1 days and a mean of 6.2 days to travel the 9 km (Figure A-22). Similar proportions of *O. mykiss* and coho spent more than 5 days traveling this distance (16% and 15% respectively). The maximum travel time for coho was 73 days, which was less than half of the maximum for *O. mykiss* (157 days).

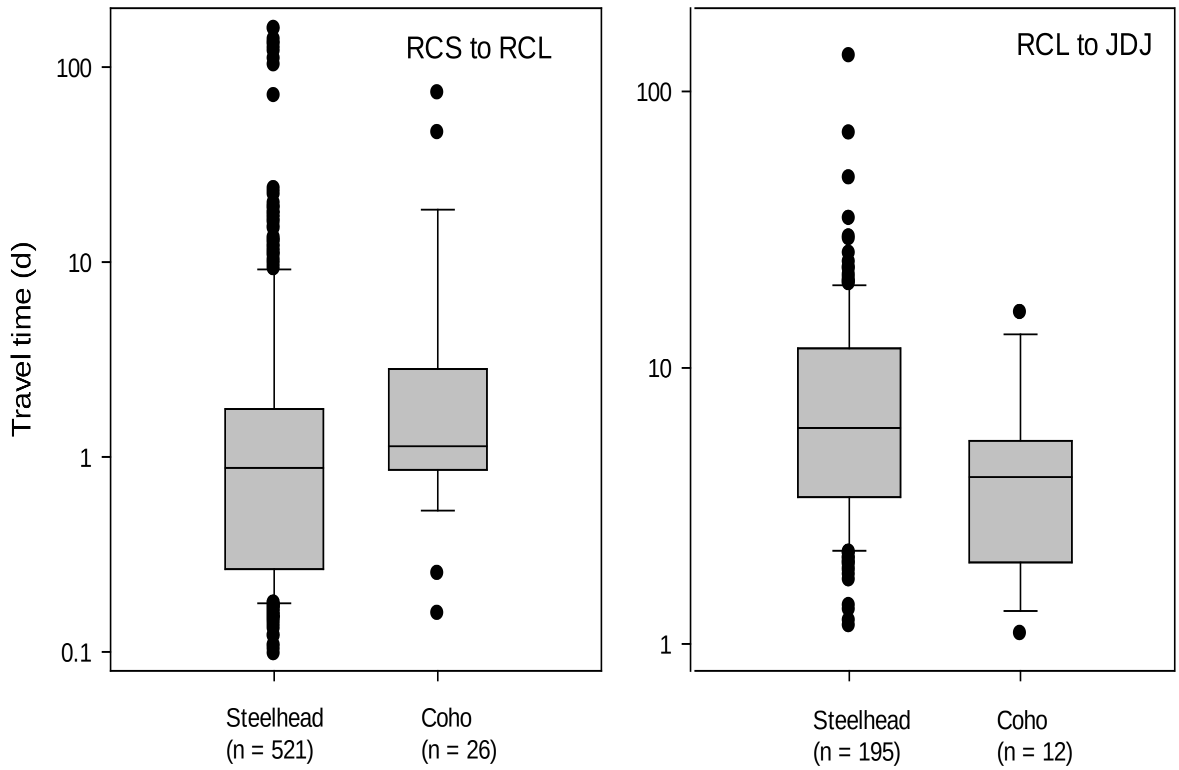


Figure A-22. Travel time of steelhead and coho smolts from PIT-tag detection systems in Rock Creek at the Squaw Creek confluence (RCS, rkm 13) to Rock Creek at rkm 5 (RCL) and from RCL to the John Day Dam juvenile bypass facility (JDJ), which was 21 km downstream of Rock Creek's confluence with the Columbia River. Note the log scale of the vertical axis and the different scale of each plot.

Travel times from RCL to the John Day Dam juvenile bypass facility at rkm 347 (a total of 26 km) were typically less for coho (n = 12, median = 4.0, mean = 4.8, max = 16) than for *O. mykiss* (n = 195, median = 6.0, mean = 9.5, max = 134; Figure A-22). This suggests that coho were more actively migrating than some of the *O. mykiss*, which were continuing to rear between these sites. It is possible that the *O. mykiss* were rearing in the lower 5 km of Rock Creek instead of the Columbia River, but additional PIT-tag detection sites, or different technology would be needed to determine this definitively.

As of November 2013, 9 steelhead and 4 coho tagged by us in Rock Creek as juvenile fish have been detected at Bonneville Dam (rkm 234) as returning adults (Tables A-5 and A-6). Of those fish, 6 of the 9 steelhead and all four of the coho were detected at The Dalles Dam at rkm 308, whose PTIS was only operational after spring of 2013. These four coho entered Rock Creek as returning adults in early December 2013. Five of the adult steelhead detected in the Columbia River swam past Rock Creek and over McNary Dam at rkm 470, typically in November. McNary Dam is about 100 km farther upstream than Rock Creek. Three of these steelhead subsequently returned to Rock Creek, all of them tagged in October of 2009 (one tagged in Rock Creek at rkm 21, two tagged in Squaw Creek at rkm 3 and rkm 8). These data are incomplete, as some of these fish were still migrating in the Columbia River at the time of this writing. We expect more adult steelhead, tagged in Rock Creek as juvenile fish, to return in the winter of 2014 through 2017.

Although a small percentage of fish PIT-tagged in Rock Creek for this study would be expected to have completed the journey back to Rock Creek as adults, 34 adult steelhead and 6 coho tagged by other agencies elsewhere in the Columbia River have been detected in Rock Creek. All six of the coho were tagged as adults below Bonneville Dam and were detected in Rock Creek, one on January 1, 2012, and the other five in from November 21 through December 4, 2012. Only one of the six coho was adipose fin clipped. Of the steelhead, 14 fish were tagged as adults at or downstream of Bonneville Dam, and 20 fish were tagged as juveniles. Nine of the 34 steelhead (26%) were hatchery fish (adipose fin clipped). It is difficult to know the origin of the fish tagged as adults at or downstream of Bonneville Dam, but we do know the tagging location and likely origin of most of the fish that were tagged as juveniles, and one adult steelhead tagged at Priest Rapids Dam. Seventeen (85%) of the juvenile fish were tagged or released in the Snake River or one of its tributaries, including 11 (55%) that were tagged and barged from Lower Granite Dam. Two steelhead were tagged at John Day Juvenile Bypass and one was tagged in Trout Creek (a tributary of the Deschutes River). Seven of the steelhead tagged as juveniles were of hatchery origin (Clearwater, Hagerman, Irrigon, and Magic Valley hatcheries). All of the known origin hatchery fish were stocked in Snake River tributaries. Twenty-six of the 34 adults (76%) that were detected in Rock Creek swam past Rock Creek and were detected in the McNary Dam adult fish ladder (seven of them climbed the McNary Dam ladder and fell back twice), typically during August through November. Several traveled through dams in the lower Snake River or Priest Rapids Dam on the Columbia River before falling back and entering Rock Creek. Adult steelhead typically entered Rock Creek during late January through April. Nineteen (55%) traveled and likely spawned upstream of Squaw Creek. Four of the adult steelhead were detected at the Bonneville Dam corner collector after leaving Rock Creek, likely as post spawn kelts. Two of these fish have been re-detected at Bonneville Dam as potential repeat spawners. We expect additional data regarding returning PIT-tagged fish over the next few years as the fish tagged in Rock Creek complete their life cycle.

Steelhead Smolt Survival

Fish tagged in Rock Creek below the Squaw Creek confluence were detected outmigrating at a significantly higher rate (39%, 95% CI = 33 to 46%) than those tagged above (26%, 95% CI = 25 to 28%, $P<0.0001$). This potentially indicated less of a resident life history in lower Rock Creek; however, we cannot separate mortality and residency using this method as apparent survival is the proportion of tagged fish that were detected at the most upstream detection site and combines mortality with resident or non-migratory fish. We found no difference in outmigration rates/apparent survival to RCS between fish tagged in Rock Creek above the Squaw Creek confluence (28%) and those tagged in Squaw Creek (25%). There was also no significant difference in apparent survival to RCL and sites in the Columbia River of fish tagged in Squaw Creek or those tagged in Rock Creek upstream of the Squaw Creek confluence. There was insufficient sample size to estimate apparent survival based on tagging or outmigration date. The model with the most support using the delta AIC method was one that only included the survival reach (survival to detection at a PTIS, Table A-7). Therefore, outmigration date and these two reaches were combined in further analysis of survival rates. Survival of fish from the RCS site to the RCL site was 91% (95%CI = 87 to 94%) and survival to John Day was 86% (95% CI = 48 to 94%). There was higher standard error for survival estimates in the Columbia River because of low detection probability and therefore low sample size downstream of RCL.

Table A-7. The model selection results of steelhead survival models from 1,457 *O. mykiss* PIT tagged in Rock Creek upstream of Squaw Creek, 1,065 PIT tagged in Squaw Creek, and 514 PIT tagged in Rock Creek downstream of Squaw Creek, which were considered tagging location (tl). The reaches between locations of detection were considered survival reaches (sr). Locations of detection were Rock Creek at the Squaw Creek confluence (rkm 13), Rock Creek at river kilometer 5, John Day Dam, Bonneville Dam, and the estuary trawl at the mouth of the Columbia River. Phi estimated survival and "p" estimated the probability of detection. The full model (sr*tl) had 12 degrees of freedom.

Model	Delta AICc	AIC Weight	Model likelihood	Number of parameters	Deviance
{phi (sr) p (sr)}	0	0.98	1	9	76
{phi (sr*tl) p (sr*tl}	7.6	0.02	0.02	17	67
{phi (.) p (.)	854.1	0	0	2	944
{phi (tl) p (tl)}	855.7	0	0	4	941

Detection efficiencies were higher at RCS (79%, 95% CI = 75 to 82%) and RCL (91%, 95% CI = 87 to 94%), than John Day Dam (37%, 95% CI = 26 to 46%). Because of the lower detection efficiency at John Day Dam and other detection facilities on the Columbia River (Bonneville Dam and the estuary trawl), we were unable to get precise estimates of survival from RCL to John Day Dam. This includes the inundated portion of Rock Creek that likely has increased sources of mortality (piscivorous fish and birds).

Discussion

The potential importance of intermittent streams to salmonids is known (Wigington et al. 2006, Everest 1973, Zimmerman and Reeves 1999). Although much of Rock Creek had intermittent flow from mid-June through November, we found a robust trout population, with *O. mykiss* surviving in the fall in most sampled pools upstream of rkm 8. Downstream of rkm 8, it appeared that salmonid survival over the summer was more uncertain, as few *O. mykiss* were collected in this area in the fall of both 2009 and 2012. Temperatures were warmer and piscivorous fish were present in these most downstream pools. Competitive exclusion of *O. mykiss* from these warmer pools may explain their reduced survival into the fall (Thompson et al. 2012). *O. mykiss* did not survive in many of the other pools in Rock and Squaw creeks, which became too shallow as the summer progressed and temperatures approached unsuitable levels for *O. mykiss*. However, it appeared that mortality was largely due to lack of water in these pools rather than high water temperatures. As pools became shallow, the maximum temperatures increased rapidly and approached lethal levels. When we re-sampled these pools in the fall, they were typically very small and shallow (less than 10 cm deep), and either no fish were found, or occasionally a few age-0 speckled dace were still surviving in the remaining pools (likely having burrowed into the interstitial spaces between the cobble). The salmonids in those pools may have died from high temperature, but more likely the salmonid mortality was from desiccation as the pools dried, or from terrestrial and avian predators. Common garter snakes *(Thamnophis sirtalis)* and great blue herons *(Ardea herodias)* were routinely observed where pools were so shallow that escape was limited. Complete loss of pool habitat units in intermittent streams can be a substantial source of mortality in some streams (May and Lee 2004), and this was also likely the case in Rock Creek. While 25°C is generally considered the lethal limit for *O. mykiss* (Hokanson et al. 1977, Benhke 1992, Thurow et al. 1997), others have found interior Columbia River rainbow (redband) trout to persist in streams with maximum daily water temperatures up to 29°C (Bowers et al. 1979, Zoellick 1999, Rodnick et al. 2004). Optimal water temperature for redband trout is below 21°C (Bowers et al. 1979), and in Rock Creek we recorded maximum summer water temperatures at or below 21°C at nearly all sites, except in the lowermost few kilometers.

The sections of Rock and Squaw creeks that had perennial pools were consistent between years, and salmonids were abundant in those perennial pools. Mean late summer densities of age-1 and older *O. mykiss* in pools of small streams typically fall below the range of 0.1 to 0.2 fish per m^2 (e. g. Everest et al. 1988, Roper et al. 1994, Reedy 1995 as referenced in Sloat and Osterback 2013). In Rock Creek, we calculated *O. mykiss* abundance ranging from 0.1 to 4.8 fish per m^2 in individual pools (averaging 0.6 age-1 and older *O. mykiss* per m^2 in 2011 and 0.4 age-1 and older *O. mykiss* per m^2 in 2012). The habitat appeared to be fully seeded with age-0 *O. mykiss* in the spring, including pools that would become unsuitable for fish survival over the summer, and there appeared to be strong density-dependent mortality over the summer. In the spring, we found the abundance of age-0 *O. mykiss* to be notably different between 2011 (high), and 2012 (low); however, the age-0 *O. mykiss* abundance in the fall was similar in both years. This was likely because the main driver of age-0 salmonid abundance was the over-summer habitat availability. The age-0 *O. mykiss* are known to be territorial, aggressive, and have high density-dependent mortality rates that regulate population size (Quinn 2005). While most density-dependent processes are negative (higher density reduces survival), some effects can be positive, such as the increase in an individual fish’s ability to avoid predators (Milner et al. 2003). An increase in habitat complexity in the perennial pools could increase the potential carrying capacity by providing protection from predators, reduced displacement by dominant fish, increased food availability, and isolation from competitors during this critical period (Dolloff and Warren 2003).

The abundance of age-1 and older *O. mykiss* was also likely regulated by over-summer habitat availability. Reduced stream flow has been shown to reduce growth of *O. mykiss* in small streams (Harvey et al. 2006). Similarly, growth of *O. mykiss* in Rock Creek was likely reduced due to low stream flow and increased competition over the summer; however, growth was still positive for almost all recaptured fish during that time. This occurred even during what was likely a stressful time, with only subsurface flow into the pools. There were likely strong interactions between the different age classes of *O. mykiss* and also between the other species inhabiting the isolated pools. As with age-0 fish, an increase in habitat complexity in the residual pools would likely increase overall carrying capacity and *O. mykiss* production by reducing intraspecific competition (Dolloff and Warren 2003). Once Rock Creek stream flow resumed in the fall, the *O. mykiss* that survived probably experienced lower densities and higher food resources. This could provide higher survival and growth than perennial streams during this period by releasing density dependence (Chapman 1966).

Intermittent streams are known to be important for coho salmon production (Wigington 2006); however, we did not expect to find them in such abundance in Rock Creek in 2011. Rock Creek often does not have surface flow until December, which likely prevents some fall spawning salmon from homing and migrating to spawn. In some years, conditions in Rock Creek are conducive to coho spawning and rearing. The return of adult coho, PIT tagged in Rock Creek as juvenile fish, suggests that Rock Creek has the potential to maintain a viable coho population and contribute to coho production overall. Additional years of study would be needed to determine whether our results in 2011 are typical for coho in Rock Creek.

Smallmouth bass are unlikely to be a significant source of mortality for the salmonids in Rock Creek during the summer, as they were only observed in the lowermost portion of Rock Creek. They are also unlikely to be a significant source of mortality during the smolt outmigration period, since the apparent survival from RCS to RCL was estimated to be 91% and we did not find them in this reach. Smallmouth bass and other piscivores may be a greater source of mortality for salmonids in the inundated portion of Rock Creek (rkm 0 to 2); however, we did not assess the fish population in this reach. We did estimate survival of smolts passing from RCL to the John Day Dam juvenile bypass facility to be 86%; however, the precision of this estimate was low. It would be possible to refine this estimate with additional PIT-tagging of juvenile salmonids. This survival estimate could also be further refined with the installation of an additional PTIS at the Highway 14 bridge (rkm 0). A focused assessment of the influence of altered hydrologic conditions and introduced predator species on salmonid survival within the inundated portion of Rock Creek would be needed to better understand if this reach is a potential bottleneck for the Rock Creek salmonid population.

Returning steelhead may either have some difficulty homing to Rock Creek earlier in the migration season when Rock Creek discharge was low, or steelhead were straying into Rock Creek because they were unable to find the location of their origin (lost). Most of the adult steelhead entering Rock Creek (76%) first traveled past McNary Dam (100 km farther upstream) before falling back and entering Rock Creek. Adult steelhead may have fallen back at John Day Dam as well as at McNary Dam before entering Rock Creek, but the was no PIT-tag detection in the adult fish ladders at John Day Dam and therefore no specific information about John Day Dam adult fish passage. Boggs et al. (2004) found that high proportions (45 to 78%) of adult radio-tagged steelhead reascended fishways at John Day Dam after falling back. They also found that 18 to 31% of the radio-tagged steelhead ascended and fell back at McNary Dam before entering tributaries downstream of McNary Dam such as Rock Creek. That fish bound for Rock Creek swim past Mc Nary Dam highlights the need for non-turbine passage routes at the Columbia River mainstem dams for adult salmonids during the winter. Typically, during the winter months, only turbine passage routes were available, since there was no spill during that period and the extended-length submersible barrier screens were not in place, potentially subjecting the fish to significant injury (Ham et al. 2012). In the Columbia River, other than harvest, the greatest attributable loss of adult migrants was tied to fallback over dams (Keefer et al. 2005).

The preliminary results of CRITFC's coordinated genetic analysis of juvenile *O. mykiss* collected in Rock Creek supported our conclusion, via PIT-tag interrogation results, that fish of Snake River origin were straying into Rock Creek and that they were a significant proportion of the steelhead spawning population. About half of the adult steelhead, which were tagged as juveniles by other agencies, that we detected in Rock Creek, were barged from Lower Granite Dam on the Snake River as juvenile fish. Hatchery steelhead made up a quarter of the adult steelhead entering Rock Creek during the spawning season, and all of the known-origin hatchery fish were stocked in the Snake River. Transporting juvenile salmonids in barges around the dams in the mainstem Snake and Columbia rivers is known to impair adult migration by increasing the likelihood of fallback at the dams and increasing stray rates (Keefer et al. 2008). While some straying of steelhead is natural (Quinn 2005), an unnaturally high proportion of stray steelhead in Rock Creek probably negatively affects the native steelhead population (Araki et al. 2007, Chilcote 2003). The effect is worsened because the population size of the native steelhead spawning in Rock Creek is small (Nehlsen et al. 1991). Introgression and competition between wild and hatchery fish can bring in genetic changes that reduce fitness (Reisenbichler and Rubin 1999) and lower productivity (Chilcote 2003). Although the naturally spawning hatchery steelhead may contribute to overall smolt production in Rock Creek, their reproductive success may be low, while they compete with native fish for spawning and the limited over-summer rearing habitat, causing further decline in the native wild population (Kostow et al. 2003).

In summary, we found Rock Creek to be a productive seasonally intermittent stream, with the ability to successfully rear steelhead and coho salmon to the smolt life stage. The stream sections that had perennial pools and surface flow were identified and were consistent among the survey years. Water temperatures were high, but rarely lethal for *O. mykiss*. The low-flow summer period with isolated pools was likely the primary factor limiting overall productivity. However, salmonids were able to survive, grow, and outmigrate, with some returning as adults to complete the lifecycle (data collection in this regard are ongoing and incomplete). The Columbia River hydropower system inundated lower Rock Creek, potentially reducing homing cues, and restricting the free movement of returning adult steelhead. McNary Dam was likely reducing the survival of returning adult Rock Creek steelhead in particular. The straying and spawning of Snake River steelhead in Rock Creek may have diluted unique genetic adaptations of steelhead native to Rock Creek, compromising the native steelhead population. When the remainder of the fish that were PIT-tagged in Rock Creek have a chance to successfully return to spawn, we will have a better understanding of the smolt-to-adult return rates and the locations that provide suitable habitat and contribute to the steelhead population.

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References

Araki, H., B. Cooper, and M. S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318:100–103.

Behnke, R.J. 1992. Native trout of western North America. Monograph 6. American Fisheries Society, Bethesda, Maryland

Boggs, C. T., M. L. Keefer, C. A. Peery, T. C. Bjornn, and L.C. Stuehrenberg. 2004. Fallback, reascension, and adjusted fishway escapement estimates for adult Chinook salmon and steelhead at Columbia and Snake River dams. Transactions of the American Fisheries Society 133:932–949.

Bowers, W., B. Hosford, A. Oakley, and C. Bond. 1979. Wildlife habitats in managed rangelands – the Great Basin of southeastern Oregon. Gen. Tech. Rep., PNW-84, USDA Forest Service.

Bunch, A. J., C. J. Walters, and L. G. Coggins Jr. 2013. Measurement Error in Fish Lengths: Evaluation and Management Implications, Fisheries, 38:7, 320-326.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Inference: A Practical Information-Theoretical Approach. 2nd edition. New York: Springer-Verlag.

Chapman, D. G., 1951, Some properties of the hypergeometric distribution with applications to zoological sample censuses: University of California Publications in Statistics 1:131–160.

Chapman D. W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist 100:345–55.

Chilcote, M. W. 2003. Relationship between natural productivity and the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (Oncorhynchus mykiss). Canadian Journal of Fisheries and Aquatic Sciences 60:1057–1067.

Columbia Basin Fish and Wildlife Authority. 1999. PIT Tag Marking Procedures Manual: Portland, Oregon, Columbia Basin Fish and Wildlife Authority, PIT Tag Steering Committee, 26 p.

Cooch, E. and G. White 2010 (9th edition). Program MARK: a gentle introduction. Available online in PDF format at: http://www.phidot.org/software/mark/docs/book/

Dolloff, C. A., and M. L. Warren. 2003. Fish relationships with wood in small streams, in S. V. Gregory, K.L. Boyer, and A.M Gurnell. eds., The Ecology and management of wood in world rivers: American Fisheries Society, Symposium 37, Bethesda, Maryland, p. 179–194.

Dunham, J. B., N. D. Chelgren, M. P. Heck, and S. M. Clark. 2013. Comparison of electrofishing techniques to detect larval lampreys in wadeable streams in the Pacific Northwest, North American Journal of Fisheries Management 33(6):1149-1155.

Everest F. H., 1973. Ecology and management of summer steelhead in the Rogue River. Portland, OR: Oregon State Game Commission. Fisheries Research Report 7.

Everest, F. H., G. H. Reeves, and J. R. Sedell. 1988. Changes in habitat and populations of steelhead trout, coho salmon, and Chinook salmon in Fish Creek, Oregon, 1983‑1987, as related to habitat improvement. Annual Report. Prepared by US Forest Service for Bonneville Power Administration, Portland, Oregon.

Ham, K. D., P. S. Titzler, R. P. Mueller, D. Trott. 2012. Hydroacoustic evaluation of adult steelhead fallback and kelt passage at McNary Dam, Winter 2010-2011. Battelle Pacific Northwest Division Report to the U.S. Army Corps of Engineers, Walla Walla, Washington. Available:http://www.salmonrecovery.gov/Files/2011%20APR%20files/New%20Folder%203/Ham_et_al_2012_-_Steelhead_Fallback_and_Kelt_Passage_McNary.pdf (December 2013).

Harvey, E. 2013. Rock Creek fish and habitat assessment for prioritization of restoration and protection actions - 2010 Annual Report, BPA Project No. 2007-156-00, March 2013. Available: https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P131998 (December 2013

Harvey, B. C., R. J. Nakamoto, and J. L. White. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. Transactions of the American Fisheries Society 135:998-1005.

Hokanson, K. E., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, Salmo gairdneri. Journal of Fisheries Research Board of Canada. 34:639-648.

Keefer, M. L., C. A. Peery, W. R. Daigle, M. A. Jepson, S. R. Lee, C. T. Boggs, K. R. Tolotti, and B. J. Burke. 2005. Escapement, harvest, and unknown loss of radio-tagged adult salmonids in the Columbia River–Snake River hydrosystem. Canadian Journal of Fisheries and Aquatic Sciences 62:930–949.

Keefer, M. L., C. C. Caudill, C. A. Peery, and S. R. Lee. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications 18(8):1888-1900.

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2013. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society 132(4):780-790.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors: Water Resource Inventory Area 31. Washington State Conservation Commission.

May, C. L., and D. C. Lee. 2004. The relationships among in-channel sediment storage, pool depth, and summer survival of juvenile salmonids in Oregon Coast Range streams. North American Journal of Fisheries Management 24:761–774.

Milner, N. J., J. M. Elliott, J. D. Armstrong, R. Gardiner, J. S. Welton, and M. Ladle. 2003. The natural control of salmon and trout populations in streams. Fisheries Research 62:111–125.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4–21.

NOAA (National Oceanic and Atmospheric Administration). 2005. Updated Status of Federally Listed ESU's of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66.

PSMFC (Pacific States Marine Fisheries Commission). 2009. Columbia basin PIT tag information system (PTAGIS). PSMFC, Gladstone, Oregon. Available: ptagis.org. (December 2013)

Quinn, T. P. 2005. The ecology and behavior of Pacific salmon and trout. University Press, Seattle, Washington. 320 p.

Reedy, G.D. 1995. Summer abundance and distribution of juvenile Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss) in the Middle Fork Smith River, California. Master's thesis, Humboldt State University, Arcata, California.

Reisenbichler, R. R., and S. P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science 56:459–466.

Rodnick, K. J., A. K. Gamperl, K. R. Lizars, M. T. Bennett, R. N. Rausch, E. R. Keeley. 2004. Thermal tolerance and metabolic physiology among redband trout populations in southeastern Oregon. Journal of Fish Biology 64:310–335.

Roper, B.R., Scarnecchia, D.L., and La Marr, T.J. 1994. Summer distribution of and habitat use by Chinook salmon and steelhead within a major basin of the South Umpqua River, Oregon. Transactions of the American Fisheries Society 123:298‑308.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters (2nd ed.): New York, Macmillan.

Sloat, M. R. and A. K. Osterback. 2013. Maximum stream temperature and the occurrence, abundance, and behavior of steelhead trout in a southern California stream. Canadian Journal of Fisheries and Aquatic Science 70:64-73

Temple, G.M., and T.N. Pearsons, 2007. Electrofishing—Backpack and drift boat, in D.H. Johnson, B.M. Shrier, J.S. O`Neal, J.A. Knutzen, X. Augerot, T.A. O`Neil, and T.N. Pearsons, eds., Salmonid field protocols handbook—Techniques for assessing status and trends in salmon and trout populations: Bethesda, Maryland, American Fisheries Society, p. 95–132.

Thompson, L.C., J. L. Voss, R. E. Larsen, W. D. Tietje, R. A. Cooper, and P. B. Moyle, 2012. Southern steelhead, hard woody debris, and temperature in a California central coast watershed. Transactions of the American Fisheries Society 141:275‑284.

Thurow, R.F., D.C.Lee, and B. E. Rieman. 1997. Distribution and status of seven native salmonids in the interior Columbia River basin and portions of the Klamath River and Great Basins. North American Journal of Fisheries Management 17:1094–1110.

Watershed Professionals Network (WPN). 2009. WRIA 31 Instream Habitat Assessment. Grant No. G0900072. Available:http://www.klickitatcounty.org/NaturalR/fileshtml/2008WRIA31/WRIA31-IHA-InstreamHabitatAssessment-20090731-Final.pdf (December 2013)

Westhagen, P., and S. R. Skalski. 2007. PIT pro 4 user's manual. University of Washington, Seattle. Available: cbr.washington.edu/paramest/ pitpro/manual/pitro v4 manual/pitpro4 manual.pdf. (December 2013).

Wigington, P. J., and 12 others. 2006. Coho salmon dependence on intermittent streams. Frontiers in Ecology and the Environment 4(10):513-518.

Zoellick, B.W. 1999. Stream temperatures and the elevational distribution of redband trout in southwestern Idaho. Great Basin Naturalist 59:136–143.

Zimmerman, C. E., and G. H. Reeves 1999. Steelhead and resident rainbow trout: early life history and habitat use in the Deschutes River, Oregon. Oregon State University report prepared for Portland General Electric Company. 75 pages.

Report B: Adult fish and habitat assessments

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Spawning surveys

Spawning surveys provide a means of monitoring annual escapement as well as spawning distribution of adult anadromous fish. Spawning surveys were conducted to monitor spatial and temporal redd distribution of fall Chinook, coho, and steelhead, and to collect biological data from carcasses. Stream reaches were surveyed multiple times during the spawning seasons, with most reaches receiving at least 2-3 passes, conducted approximately two weeks apart in each reach. Subsequent survey passes generally continued in each reach until no live spawners were observed. Methods generally followed those of Gallagher et al. (2007). Scale samples were also taken from carcasses using methods outlined in Crawford et al. (2007).

One-man pontoon and foot surveys were conducted within the known geographic range for each target species where access was physically possible and permission was granted. Individual salmon or steelhead redds were counted and their locations recorded using handheld Global Positioning System (GPS) units. Counts of live fish and carcasses were also recorded. Carcasses were examined to determine sex, egg/milt retention (percent spawned), and presence of Coded Wire Tags (CWT) or external experimental marks. We attempted to cover as much as possible of the presumed spawning range of each species, although for steelhead, some gaps in survey coverage exist. Access to the headwaters of Rock (upstream of RM 20), Quartz (upstream of RM .5) and Squaw (upstream of RM 5) creeks is very challenging due to steep canyon walls and lack of roads, which limited the ability to conduct surveys upstream of those rivermiles during a regular work day. Spawning surveys in Luna Creek were limited to the lowest .5 rivermiles because one landowner did not provide access to their property. Fall Chinook surveys were conducted from early November through late December; coho surveys were conducted from late October through late February; steelhead surveys began in January and continued through late May. The lower to middle reaches of Rock Creek have intermittent flow and no connectivity during the summer and early fall months: fall Chinook and coho spawning habitat availability is limited to years when there is actual instream flow during the spawning season.

Neither fall Chinook nor coho spawning seems to be consistent enough year to year to lead to viable spawning populations of those stocks in Rock Creek. The low cumulative numbers of actual observed live adults, redds, and carcasses of fall Chinook and coho in Rock Creek are reflective of survey conditions; instream flow is variable year to year during the fall and early winter months, depending on fall precipitation. A tabular summary of spawning survey results by species in Rock Creek is presented in Tables B-1 to B-4 for the years 2008-2013.

Fall Chinook

Fall Chinook surveys were conducted from early November through late December, covering approximately 2.5 river miles. Table B-1 shows results for fall Chinook redd counts in the Rock Creek subbasin for the 2008–2012 spawning seasons. The majority of observed spawning occurs adjacent to the Army Corps of Engineers' park at the Rock Creek confluence (where the flowing Rock Creek meets the impounded area backed up by the Columbia River behind John Day Dam, Lake Umatilla). In 2008, a total of 2 redds, 2 live adults, and no carcasses were observed. For 2009, there were no redds, no live adults or carcasses found in the 2.5-mile reach; there was insufficient instream flow and connectivity to allow fish passage upstream of the confluence of Rock Creek. For the 2010 spawning season, 6 redds, 2 live adults, and 2 carcasses were recorded. In the 2011 and 2012 spawning seasons, no redds, no live adults or carcasses were observed due to lack of instream connectivity at the confluence of Rock Creek.

Table B-1. Results of fall Chinook spawning surveys in Rock Creek subbasin, 2008-2012.

Results of Fall chinook spawner surveys in the Rock Creek Subbasin 2008 - 2012

Year	Stream	Reach	Surveyed Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed: Floy Tag	Live Observed: No Floy	Live Observed: Unk	Morts: No Floy	Morts: Floy Tag	Morts: Unk
2008	Rock Creek	Rock Creek conflu. to gasline	2.5	2	2	0.8	0	0	2	0	0	0
2009	Rock Creek	Rock Creek conflu. to gasline	2.5	2	0	0	0	0	0	0	0	0
2010	Rock Creek	Rock Creek conflu. to Hwy8 br.	2.5	3	6	0.4	0	0	2	0	2	0
2011	Rock Creek	Rock Creek conflu. to Hwy8 br.	2.5	2	0	0	0	0	0	0	0	0
2012	Rock Creek	Rock Creek conflu. to Hwy8 br.	2.5	3	0	0	0	0	0	0	0	0
		Mainstem Totals (surveyed reach)	2.5		8		0	0	4	0	2	0

Two fall Chinook carcasses were recovered during spawning surveys in Rock Creek in 2010 and scale samples were collected from each fish. Readable scales were collected from both adult fall Chinook. They were aged as 4-year-olds, and the fork length for both fish was 680 mm.

Coho

Coho surveys were conducted between late October through late February, covering nearly 2.5 river miles (RM) in 2008 – 2011 and 7.3 river miles in 2012, with between 2-3 passes at each survey reach. The majority of observed spawning occurs from RM 1 to RM 4.5 in the mainstem Rock Creek and RM 0 to RM 1.5 in Squaw Creek, shown in Figure B-1. For the 2008 spawning season, no coho redds, one live adult, and no carcasses were observed within the spawning reach. During the 2009 spawning season, there was a total of 16 redds, 5 live coho adults, and 8 carcasses (5 with floy tags). For 2010, a total of 2 redds, 3 live adults, and one carcass were documented in the lowermost 2.5 river miles of Rock Creek. In 2011, a total of 5 redds, 3 live adults, and 2 coho carcasses were observed. In 2012, 8 redds, 12 live adults, and 5 coho carcasses were enumerated in the Rock Creek mainstem RM 1–RM 4.89, and in Squaw Creek, 3 coho redds, no live adults, and no carcasses were found in the lowest 1.5 river miles. Coho access to spawning habitat is also limited in the fall and early winter season because of insufficient instream flow at the Rock Creek confluence.

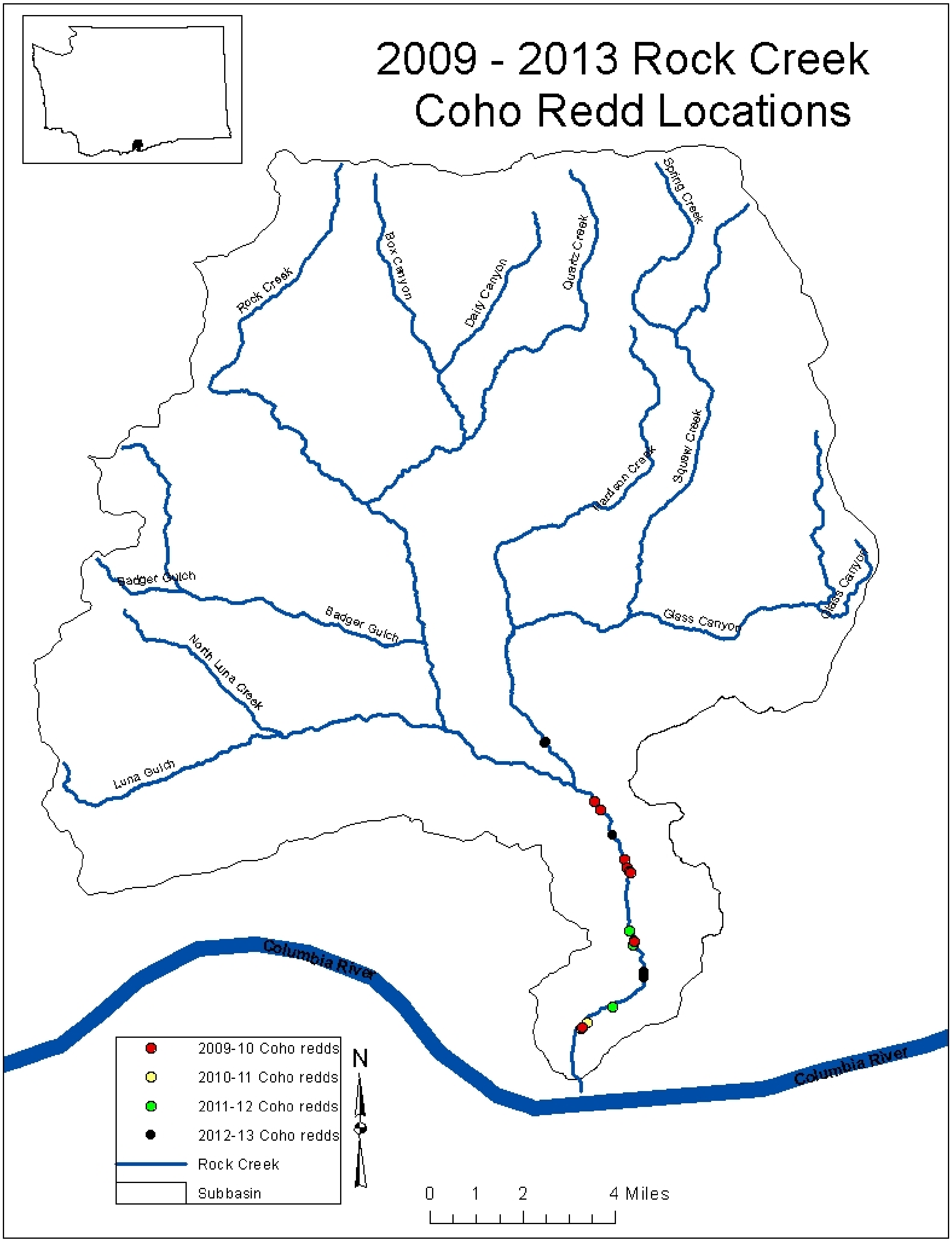


Figure B-1. Rock Creek coho redd distribution map, 2009 – 2013.

For each year surveyed, only a few (0 – 5) coho salmon carcasses were recovered during spawning surveys in Rock Creek. During the five years surveyed, a total of 16 carcasses were recovered, from which scale samples were collected. Readable scales were collected from 8 of the 16 adult coho. All of the coho samples were aged as 3-year-olds, and the fork lengths ranged from 609 mm to 900 mm.

Steelhead

Steelhead spawning surveys were conducted between January and late May, covering approximately 12 river miles in 2009, 14 river miles in 2010, and 26.77 river miles in 2011–2013, with between 2-3 passes in each survey reach. Survey reach lengths varied based on accessibility and consent to cross private land. In 2012 and 2013, the upper reaches of Rock Creek (RM 14–RM 20) were not surveyed because of safety concerns and difficult access to those reaches. Spawning surveys were conducted in the mainstem Rock Creek (RM 1–RM 20.08), Squaw Creek (RM 0-RM 5), Luna Creek (RM 0–RM .5), Badger Creek (RM 0–RM .5) and Quartz Creek (RM 0–RM .5 in 2008). High spring flows and low visibility often limited the timing and safe access to survey reaches. Steelhead spawning is widespread in the lower to middle reaches of Rock Creek and Squaw Creek, as shown in Figure B-2. Steelhead have been observed spawning in similar locations each year in the subbasin.

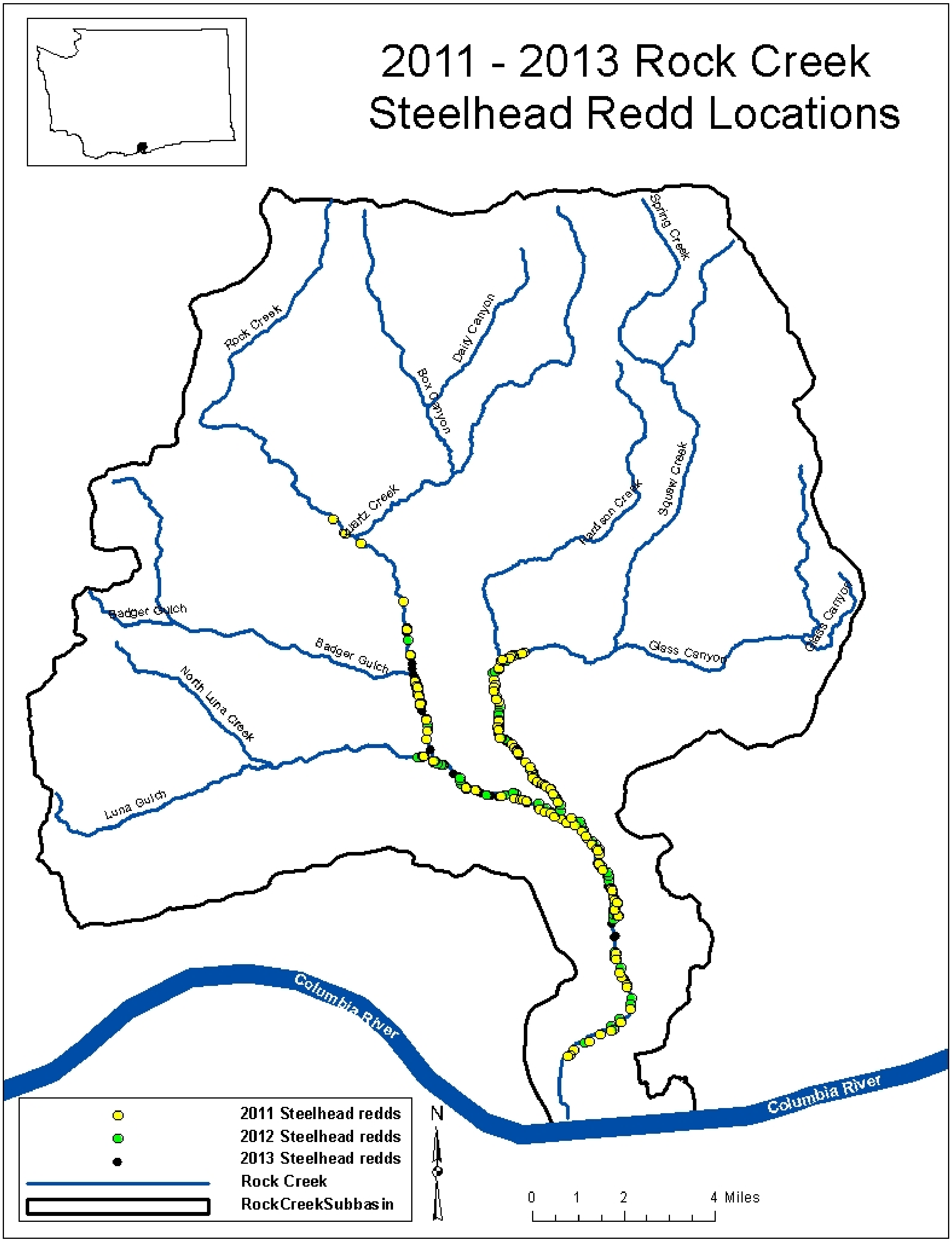


Figure B-2. Rock Creek steelhead redd distribution map 2011 – 2013.

A total of 45 steelhead redds, 37 live adults, and no carcasses were documented during the 2009 season (Table B-2). A total of 127 redds, 104 live adults, and 5 carcasses were enumerated during the 2010 spawning season (Table B-3). A total of 287 redds, 154 live adults, and 2 carcasses were recorded during the 2011 spawning season, with an additional 12 river miles surveyed compared to the previous year (Table B-3). The majority of steelhead redds observed in the mainstem Rock Creek were from RM 1-RM 13.5, and in Squaw Creek from RM 0–RM 5.5. We attempted to cover the entire presumed steelhead spawning range (80% coverage) in the subbasin in the 2011-2012 spawning seasons. In 2012, a total of 258 steelhead redds, 59 live adults, and 2 carcasses were documented in the 26.77 river miles surveyed in the subbasin (Table B-4). A total of 106 redds, 42 live adults, and 1 steelhead carcass were documented during the 2013 season. In 2013, the number of survey days was limited because of high flow and low visibility conditions (Table B-4). Survey conditions most likely biased the 2013 redd counts low. PIT-tag detection and genetics results indicate that substantial numbers of these adult steelhead are out-of-basin strays (see reports A and D for more details).

Table B-2. Results of steelhead spawning surveys in Rock Creek subbasin, 2009.

Results of 2009 Steelhead spawner surveys in the Rock Creek Subbasin

Stream	Reach	Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed Floy Tag	Live Observed No Floy	Live Observed Unk	Morts No Floy	Morts Floy Tag	Morts Unk
Mainstem	Rock Creek confl. to gasline	2.5	3	12	4.8	0	1	4	0	0	0
	Rock Creek Luna confl. to Bick. I	2.5	3	0	0	0	0	2	0	0	0
	Mainstem Totals (surveyed reach	5		12	4.8	0	1	6	0	0	0
Tributaries	Luna Gulch	1.5	3	2	1.33	0	0	5	0	0	0
	Squaw Creek at confl.	1.5	3	10	6.67	0	0	12	0	0	0
	Squaw Creek at Harrison confl.	1.5	2	16	10.67	0	0	9	0	0	0
	Harrison Creek confl.	1	2	0	0	0	0	0	0	0	0
	Badger Gulch at confl.	0.5	2	0	0	0	0	0	0	0	0
	Quartz Creek at confl.	1.5	2	5	3.33	0	0	4	0	0	0
	Tributary Totals (surveyed reache	7.5		33	22	0	0	30	0	0	0
	Rock Creek Subbasin Totals	**12.5**		**45**		**0**	**1**	**36**	**0**	**0**	**0**
	Mainstem contribution			36		~	100	17	~	~	~
	Tributary contribution			73		~	0	83	~	~	~

Table B-3. Results of steelhead spawning surveys in Rock Creek subbasin, 2010-2011.

Results of 2011 Steelhead spawner surveys in the Rock Creek Subbasin

Stream	Reach	Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed Floy Tag	Live Observed No Floy	Live Observed Unk	Morts No Floy	Morts Floy Tag	Morts Unk
Mainstem	Rock Creek boat launch to Hwy 8 Br.	3.6	3	21	5.83	2	18	0	0	1	0
	Hwy 8 Br. to Squaw Cr. confl.	5.6	3	60	10.71	0	20	14	0	1	0
	Squaw Cr. confl. to Unnamed Trib.	7.02	2	95	13.53	0	15	0	0	0	0
	Unnamed Trib. to Rock Creek Falls	4.58	2	11	2.4	0	2	2	0	0	0
	Mainstem Totals (surveyed reaches)	20.8		187	30.08	2	55	16	0	2	0
Tributaries	Luna Creek	0.5	3	5	10	0	0	5	0	0	0
	Squaw Creek confl. to end of survey	4.97	3	95	19.11	0	0	73	0	0	0
	Badger Creek at confl.	0.5	3	0	0	0	0	3	0	0	0
	Tributary Totals (surveyed reaches)	5.97		100	29.11	0	0	81	0	0	0
	Rock Creek Subbasin Totals	**26.77**		**287**		**2**	**55**	**97**	**0**	**2**	**0**
	Mainstem contribution			65		100	100	16	~	100	~
	Tributary contribution			35		0	0	84	~	0	~

Results of 2010 Steelhead spawner surveys in the Rock Creek Subbasin

Stream	Reach	Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed Floy Tag	Live Observed No Floy	Live Observed Unk	Morts No Floy	Morts Floy Tag	Morts Unk
Mainstem	Rock Creek boat launch to Squaw Cr.	6.7	3	63	9.4	0	45	0	1	2	2
	Rock Creek Luna confl. To Bick. Br.	2.5	3	26	10.4	0	18	21	0	0	0
	Mainstem Totals (surveyed reaches)	9.2		89	19.8	0	63	21	1	2	2
Tributaries	Luna Creek	1.5	3	0	0	0	0	0	0	0	0
	Squaw Creek at confl.	1.25	3	27	21.6	0	0	10	0	0	0
	Squaw Creek at Harrison confl.	1.25	2	11	8.8	0	0	10	0	0	0
	Harrison Creek at confl.	1	2	0	0	0	0	0	0	0	0
	Badger Creek at confl.	0.5	3	0	0	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	5.5		38	30.4	0	0	20	0	0	0
	Rock Creek Subbasin Totals	**14.7**		**127**		**0**	**63**	**41**	**1**	**2**	**2**
	Mainstem contribution			70		~	100	51	100	100	100
	Tributary contribution			30		~	0	49	0	0	0

Table B-4. Results of steelhead spawning surveys in Rock Creek subbasin, 2012-2013.

Results of 2013 Steelhead spawner surveys in the Rock Creek Subbasin

				Reach		Live Observed			Morts		
			#	Redds	Redds						
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unk	No Floy	Floy Tag	Unk
Mainstem	Rock Creek boat launch to Hwy 8 Br.	3.6	2	6	1.67	0	0	9	0	0	0
	Hwy 8 Br. to Squaw Cr. confl.	5.6	2	36	6.43	0	13	3	0	0	0
	Squaw Cr. confl. to Unnamed Trib.	7.02	2	42	5.98	0	0	11	0	0	1
	Unnamed Trib. to Rock Creek Falls	4.58	*	*	*	*	*	*	*	*	*
	Mainstem Totals (surveyed reaches)	20.8		84	14.08	0	13	23	0	0	1
Tributaries	Luna Creek	0.5	12	1	2.00	0	0	0	0	0	0
	Squaw Creek confl. to end of survey	4.16	2	21	5.05	0	0	6	0	0	0
	Badger Gulch at confl.	0.5	2	0	0	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	5.16		22	7.05	0	0	6	0	0	0
	Rock Creek Subbasin Totals	**25.96**		**106**		**0**	**13**	**29**	**0**	**0**	**1**
	Mainstem contribution			79		~	~	79	~	~	100
	Tributary contribution			21		~	~	21	~	~	0

**Reach was not accessible to survey in 2013*

Note: 2013 spawning surveys = 2 passes per reach

Results of 2012 Steelhead spawner surveys in the Rock Creek Subbasin

				Reach		Live Observed			Morts		
			#	Redds	Redds						
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unk	No Floy	Floy Tag	Unk
Mainstem	Rock Creek boat launch to Hwy 8 Br.	3.6	3	30	8.33	0	0	1	0	0	0
	Hwy 8 Br. to Squaw Cr. confl.	5.6	3	59	10.54	0	0	25	0	0	0
	Squaw Cr. confl. to Unnamed Trib.	7.02	3	70	9.97	0	0	12	0	0	2
	Unnamed Trib. to Rock Creek Falls	4.58	*	*	*	*	*	*	*	*	*
	Mainstem Totals (surveyed reaches)	20.8		159	28.84	0	0	38	0	0	2
Tributaries	Luna Creek	0.5	3	4	8.00	0	0	6	0	0	0
	Squaw Creek confl. to end of survey	4.97	3	95	19.11	0	0	15	0	0	0
	Badger Gulch at confl.	0.5	3	0	0	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	5.97		99	27.11	0	0	21	0	0	0
	Rock Creek Subbasin Totals	**26.77**		**258**		**0**	**0**	**59**	**0**	**0**	**2**
	Mainstem contribution			62		~	~	64	~	~	100
	Tributary contribution			38		~	~	36	~	~	0

**Reach was not accessible to survey in 2012*

On an average year, only few (0–3) steelhead carcasses were recovered on spawning surveys in Rock Creek, as steelhead could potentially survive the spawning process and migrate downstream as kelts. During the five years reported here, a total of 8 steelhead carcasses were recovered, from five of which readable scale samples were collected. Four of the five adults were aged as 3-year-olds, and one was aged as a 2-year-old fish. Fork lengths ranged from 584 mm to 820 mm.

Habitat assessment

The purpose of assessing habitat is to characterize its present state and the processes that create and maintain it, so that obstacles and appropriate restoration options can be identified and prioritized. For this study, Rock Creek and its tributaries were delineated into reaches using a USGS topographical map (1:24,000) and based on stream geomorphologic features (e.g. gradient, channel confinement, and tributary confluences). Habitat surveys were conducted on 15 stream reaches throughout the subbasin with the intent of collecting information to populate the EDT model. The information collected for each reach included width measurements at wetted channel and ordinary high water mark; frequency and length of habitat type; large woody debris counts; confinement; riparian function; sediment size and embeddedness (Murphy & Willis, 1996); (Harrelson et al., 1994).

The stream was characterized as one of the following habitat types: primary pool, large cobble riffle, small cobble riffle, pool tailout, glide, off-channel habitat, or side channel. Large woody debris counts and notes were also included in the habitat surveys, such as enumeration of wood pieces in the stream channel and in log jams. Riparian function and condition, substrate embeddedness, natural confinement, and hydroconfinement parameters were also documented for each surveyed stream reach. Habitat data for 2008–2013 were input into the Rock Creek EDT model and are stored in the Stream Reach Editor Access database. For an in-depth report describing EDT modeling for fish populations in Rock Creek, Klickitat County, WA, see Report C: *Assessment of the Rock Creek Watershed Using the Ecosystem Diagnosis and Treatment Model* (Harvey, 2014).

Implications for habitat restoration in the subbasin

The main purpose of the Rock Creek project was to understand the current habitat conditions, protect and conserve existing good quality habitat and expand on these focal areas, and to identify protection and/or restoration sites and actions. Since 2008, data have been collected throughout the basin, including water temperature, water quality, habitat, spawner abundance and redd counts, juvenile fish population abundance and distribution, steelhead genetics, fish pathogens, and steelhead life history characteristics gained from PIT-tagging and detections. A companion study was initiated 2013 led by Yakama Nation in cooperation with the Eastern Klickitat Conservation District to assess channel geomorphic conditions. That project combined with the efforts described here will help to identify and refine future project development opportunities for restoration sites in the Rock Creek subbasin.

Yakama Nation staff created relationships with many of the private landowners within the subbasin to obtain access through their property for data collection and identification of potential restoration projects. There are extensive government, tribal (not mapped), and Nature Conservancy lands in Rock Creek and its tributaries (Figure B-3) that could be considered for habitat protection and restoration. Some adjacent landowners are taking steps to protect habitat. The Nature Conservancy protects its lands from cattle grazing and conducts invasive weed removal. The Goodnoe Hills Windfarm, Inc. created a small wildlife preserve mitigation area in the lower Rock Creek riparian corridor that includes important salmonid spawning and rearing habitat with cattle exclusion fencing. A large section of the mid-reaches of Rock Creek and Squaw Creek which contains key steelhead spawning habitat is owned by a private individual who is in the process of securing conservation easements for his property at the time of the writing of this report. These easements could allow for important conservation measures, and could open opportunities for possible restoration actions in this part of the watershed. Public outreach has been conducted to local schools and summer student camps within Klickitat County about the potential for preservation and restoration activities in Rock Creek. Many local residents are supportive of the project, interested in its results, and are supportive of the restoration of salmon and steelhead in the subbasin.

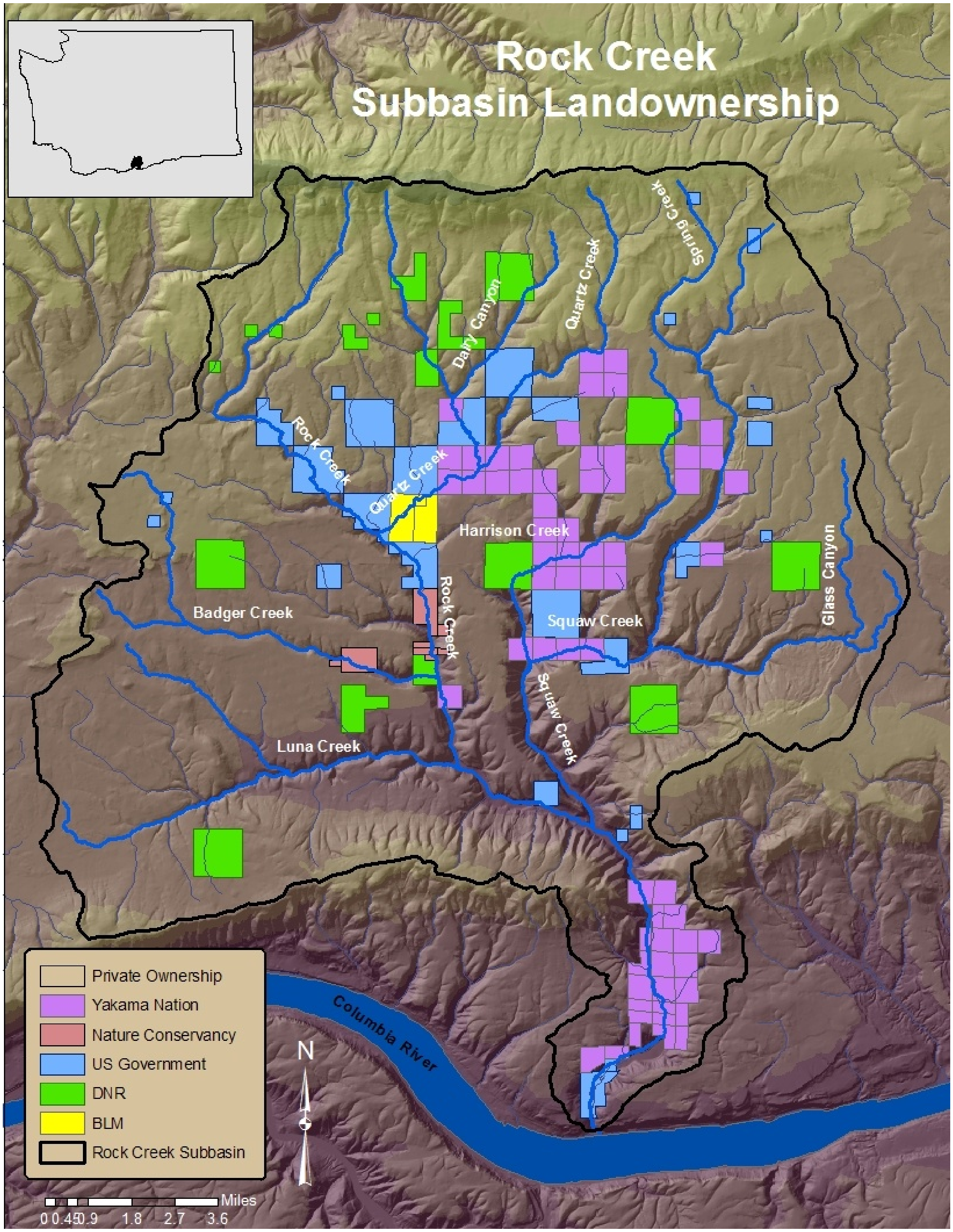


Figure B-3. Public and Yakama Nation land ownership in Rock Creek subbasin.

In the fall of 2006, the Washington State Department of Ecology (DOE) designated portions of Rock Creek, Luna Gulch, Squaw Creek, and Quartz Creek as waters requiring supplemental protection (303[d] list, "those waters that are in the polluted water category, for which beneficial uses– such as drinking, recreation, aquatic habitat, and industrial use – are impaired by pollution", WDOE http://www.ecy.wa.gov/programs/Wq/303d/index.html), and imposed a more stringent water temperature criterion during the salmonid spawning and incubation season. This designation has alerted private landowners to the water temperature issue in Rock Creek subbasin, and many wish to work together with the local conservation district, Yakama Nation, and DOE towards reducing water temperatures and removal from the 303(d) list. Since the designation of portions of the basin for the 303(d) list, some changes have been made on private property to improve water quality and temperature. Cattle exclusion from the creek and off-channel watering are two examples of landowner compliance. However, cattle grazing along and in the creek is still a problem in the Rock Creek subbasin. If there were more funding available, additional cattle exclusion fences could be constructed that would protect the riparian vegetation, allow for natural willow and tree recruitment, and create channel stability.

In 2007–2008, the U.S. Fish and Wildlife Service funded a riparian planting and cattle exclusion fence construction project in cooperation with the Yakama Nation. In 2008- 2013, additional riparian plantings of native tree species and invasive weed removal were conducted to enhance the riparian revegetation in Rock Creek between RM 3.5–RM 5 (see Chapter 4, Revegetation). Using the EDT modeling results and geomorphic assessment, more sites could be identified for future riparian revegetation projects.

For restoration purposes, access may pose a challenge in the headwaters and some mid-reaches of Rock Creek and its tributary streams. The lowest 18.6 river miles of Rock Creek and the lowest 2 miles of Squaw Creek are accessible by road for restoration. Upstream of RM 18.6 in Rock Creek and upstream of RM 2 in Squaw Creek, there are no access roads. We have been accessing upstream of these locations by walking in and out 3 miles or more to conduct surveys. If restoration were identified in those reaches, then alternative modes of transportation would have to be considered, such as a helicopter. The headwaters of Rock Creek are owned by a private timber company which, in the past few years, put the land up for sale. Yakama Nation contacted the company to inquire about accessing their property to assess the headwater conditions and look for possible meadow or wetland restoration project sites. The company is not interested in restoration, and their focus is on selling the lands.

There are funding resources available that could assist with the cost of preservation and restoration of salmonid habitat in the Rock Creek subbasin. The NMFS Middle Columbia Steelhead Recovery Plan and NPCC Rock Creek Subbasin Plan strategies along with the cumulative RM&E data collected in the subbasin over the years will be considered in the process of prioritizing locations for salmonid habitat enhancement. Spring enhancement, riparian rehabilitation, cattle exclusion fence construction, pool enhancement, floodplain reconnection, channel stabilization, and large wood placement are examples of possible restoration strategies that were identified in the salmon recovery and subbasin plans. Low or non-existent instream flow, high summer water temperatures, and lack of summer juvenile rearing habitat are a few of the main limiting factors in Rock Creek. Addressing these will be key to any habitat restoration in the basin. Various habitat parameters including air and water temperatures, water quality, and sediment were also monitored during the study period throughout the basin, see Figure B-4.

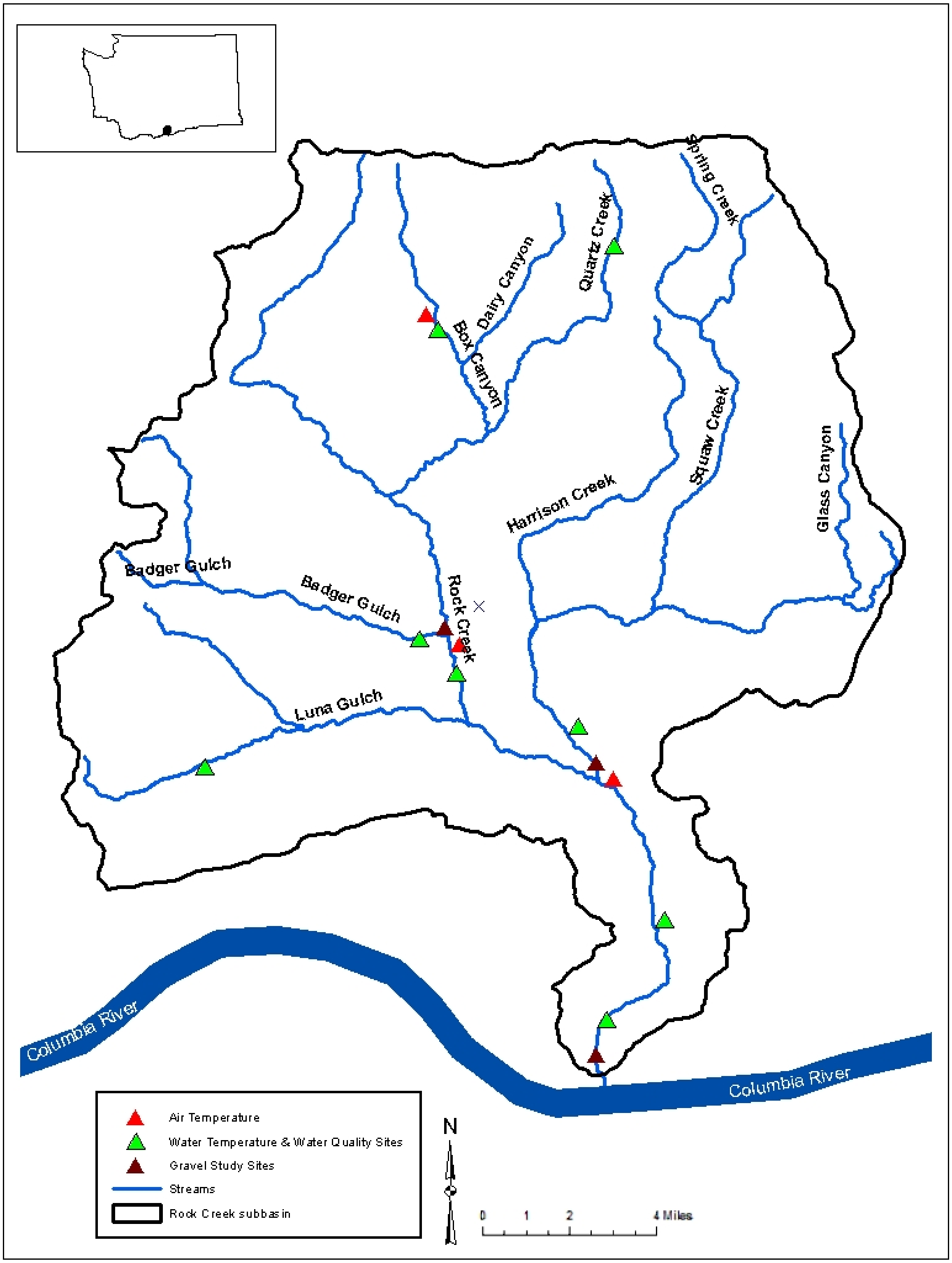
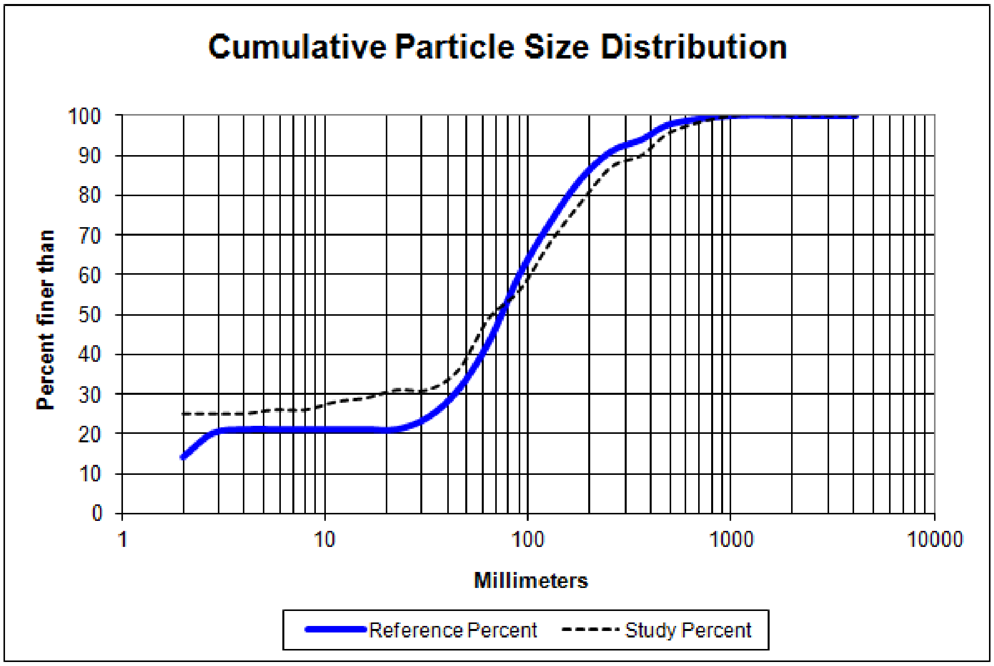


Figure B-4. Air temperature, water temperature and quality, and gravel monitoring sites in the Rock Creek subbasin.

Sediment Monitoring

Sediment and substrate conditions were monitored at selected sites in the Rock Creek subbasin during the study period using the Wolman pebble count methodology (Wolman, 1954; Bunte et al. 2001)**.** Surface substrate was sampled at two spawning sites in mainstem Rock Creek (RM 2 and RM 13.6) and one in Squaw Creek at RM 1. All three sites were sampled in 2008 (labeled as “reference” in the data figures) and again in 2011 (labeled as “study” in Figures B-5–B-7). In this report, a comparison of samples collected in 2008 and in 2011 were used to observe possible changes in fine sedimentation at three steelhead spawning locations.

The first site is of particular interest for continuous monitoring due to the Klickitat County 2009 bridge replacement project at the Bickleton Highway Bridge crossing at RM 13.6 (Figure B-5) where there is important adult holding and juvenile rearing habitat. The second site is near the Rock Creek confluence, where spawning of fall Chinook, coho, and steelhead has been observed in recent years (Figure B-6). The third site is located at RM 1 in Squaw Creek within known steelhead spawning habitat (Figure B-7). Data were also incorporated into the EDT model Stream Reach Editor (SRE) in 2013.



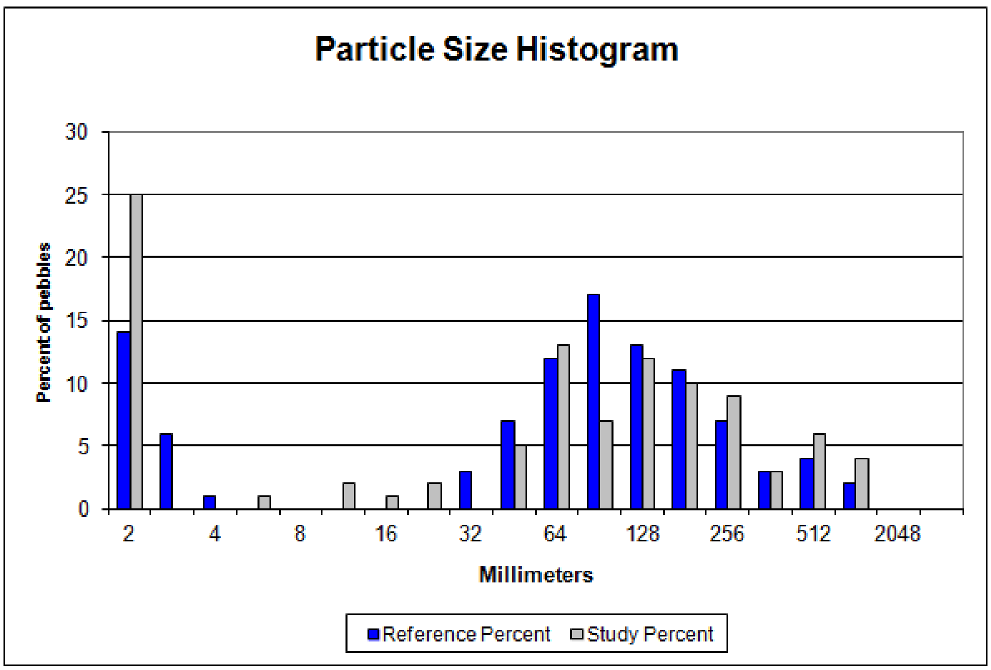
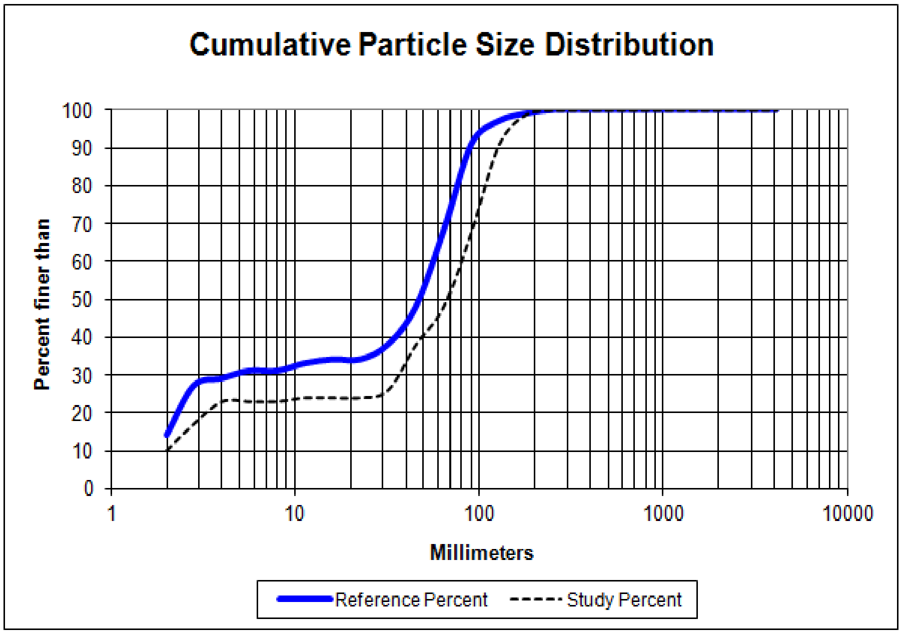


Figure B-5. Reference (2008) and study (2011) sediment particle size comparisons for Bickleton Bridge (Bridge Replacement Site), Rock Creek (RM 13).



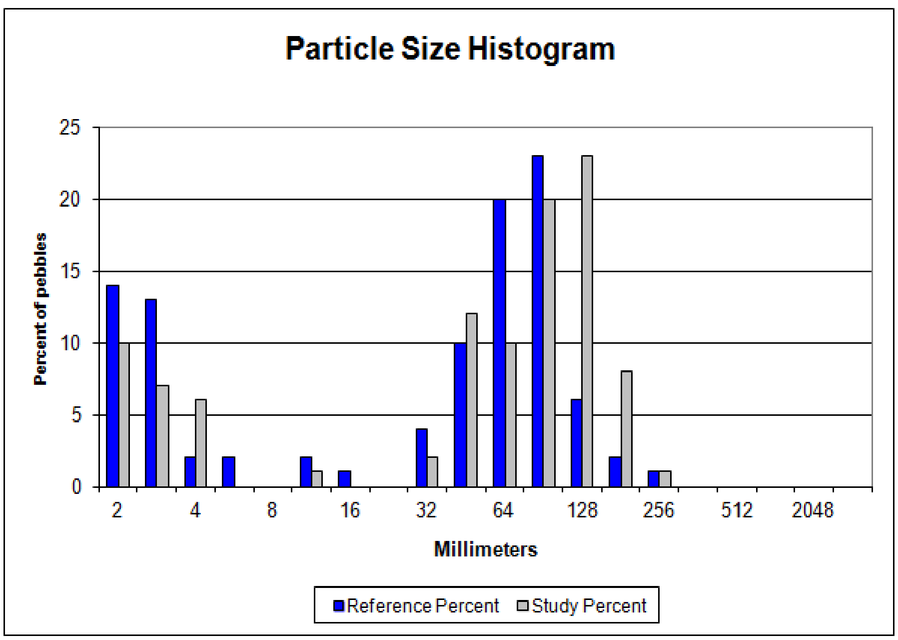
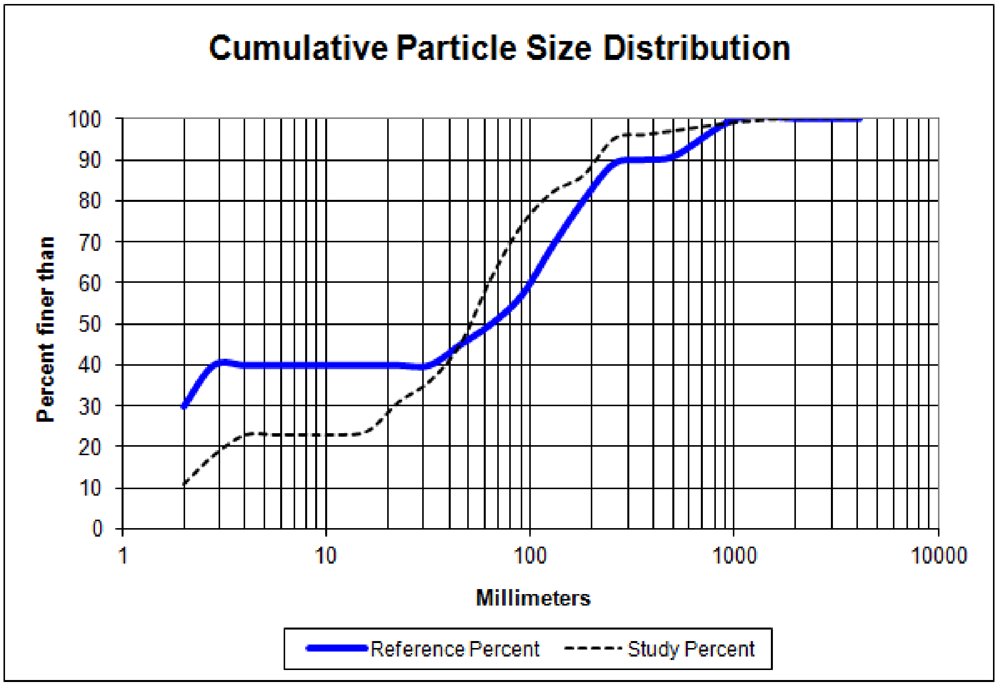


Figure B-6. Reference (2008) and study (2011) sediment particle size comparisons for Army Corps of Engineers Park of lower Rock Creek (RM 2).



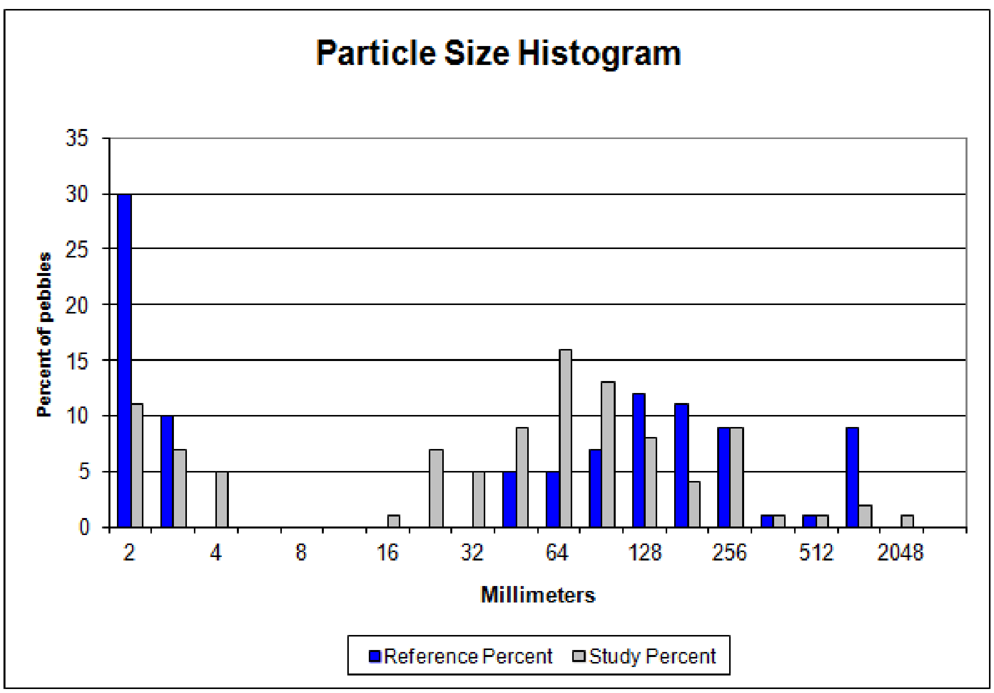


Figure B-7. Reference (2008) and study (2011) sediment particle size comparisons for Squaw Cr. (RM 1).

The average substrate type for the Army Corps Park, Bickleton Bridge and Squaw Creek sites was the small cobble type (64 -128mm, Figures B-5-B-7). There was a higher percentage of sands and fine sediments found at Bickleton Bridge site in 2011 than at the Army Corps or Squaw Creek sites. A higher level of fine sediments was anticipated for this site because of the 2009 bridge replacement, which included instream construction and bank reconstruction. The Bickleton Bridge site had an overall increase from14% in 2008 to 25% in 2011 in fine sediment material <2 mm. The Squaw Creek site had a decrease in <2 mm sands/sediments from 30% in 2008 to 11% in 2011. The Army Corps site also had a decrease in <2 mm sands/sediments from 14% in 2008 to 10% in 2011.

The Army Corps Park site had the widest bankfull width and, located near the confluence of the flowing portion of Rock Creek with the inundated pool, it was also expected to have a higher level of fine sediment than the Bickleton Bridge site. Rock Creek is a flashy system, with high flows occurring from spontaneous rain events or rain-on-snow events that have the potential to scour out existing redds or cover redds with layers of fine sediments. When high flow events occur, the creek transports large wood and substrate material that are deposited at the Army Corps Park site. In recent years, coho redds have been observed being washed out completely or covered by new gravels and fine sediments in that location.

Temperature and water quality monitoring

Air temperature, stream temperature and water quality were monitored at key locations on a seasonal basis in order to characterize the chemical and physical conditions of the subbasin, see Figure B-4. Water temperature was taken at ten sites throughout mainstem Rock Creek and its tributaries (Squaw, Luna, Badger, and Quartz creeks) in 30-minute increments using Onset Corporation Hobo temperature probes. The purpose of air temperature monitoring was to enable a quality control check of the water temperature data. During the summer months when sections of Rock Creek turn dry, the water temperature data was quality control checked against air temperatures. Basic water quality parameters were measured 3–10 times per year at eight sites (Figure B-4). Water quality measurements were taken using a YSI, Incorporated Model 85 Handheld Dissolved Oxygen, Conductivity, and Temperature meter. Parameters collected included dissolved oxygen (mg/L), conductivity (µs), turbidity and pH and temperature °C. Water temperature data collected is represented in Appendix C, Table C-i.

We monitored water quality at a total of eight sites in Rock Creek (RM 1.3, RM 5, RM 13, RM 21), Quartz Creek (RM 7.4), Badger Creek (RM 0.25), Luna Creek (RM 5.2), and Squaw Creek (RM 1). Water quality field data collection was conducted at each site only if there was actual instream flow. During the summer months, six out of eight sites went dry, and data was not collected for those sites until the fall or winter months when instream flow resumed. All water quality data are stored in the Rock Creek water quality and temperature database.

The uppermost water quality site in the Rock Creek basin is the Box Canyon Road location (RM 21) at 2,500 feet in a forested area in the headwaters. During most years, this site turns intermittent with a few remnant pools. Water quality was collected from November through June, and on some years, there was no access to the station because of high snowpack-related road closures (December – January). From January through May, the water temperature collected ranged from 3–7 ºC, dissolved oxygen ranged from 8–12 mg/L, turbidity ranged from 5–10 NTU (with 10 NTU occurring during April – high snow melt), specific conductivity ranged from 63–66 µs, and pH ranged from 8–9. From June through October, no water quality readings were collected because of stream intermittency at the monitoring site. In November and December, the water temperature ranged from 6–10 ºC, dissolved oxygen ranged from 9–12 mg/L, turbidity ranged from 0-1 NTU, specific conductivity ranged from 36–77 µs, and pH averaged 7.

The next uppermost water quality site is in the Quartz Creek headwaters (RM 7.4), also in a heavily forested area. Access to this site is restricted from December through February in some years because of high snowpack-related road closures. From January through May, the water temperature ranged from 3–8 ºC, dissolved oxygen ranged from 8–9 mg/L, turbidity ranged from 0–5 NTU, specific conductivity ranged from 59–96 µs, and pH ranged from 8–9. From June through August, the water temperature ranged from 11–15 ºC, dissolved oxygen averaged 7 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 92–96 µs, and pH ranged from 8–9. From September through October, no water quality readings were collected because of stream intermittency at the monitoring site. In November and December, the water temperature ranged from 6–10 ºC, dissolved oxygen ranged from 8–9 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 99–126 µs, and pH ranged from 6–7.

Badger Creek is a small tributary on the eastern side of the watershed; water quality was monitored at RM 0.25 near its confluence with Rock Creek. This stream became intermittent each year beginning in July and lasting through January, when no water quality was collected from the site. From January through May each year, the water temperature ranged from 3–12 ºC, dissolved oxygen ranged from 10–12 mg/L, turbidity ranged from 0–5 NTU, specific conductivity ranged from 98–160 µs, and pH ranged from 8–9. From June through July, the water temperature ranged from 13–14 ºC, dissolved oxygen averaged 5 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 180-181 µs, and pH averaged 8.

Water quality in Luna Creek was collected each month, since it retained instream flow year-round; however, during the summer months, flow was very limited. This site is located at RM 5.2 at the Oak Flat Road stream crossing. From January through May, the water temperature ranged from 3–10 ºC, dissolved oxygen ranged from 8-10 mg/L, turbidity ranged from 0–5 NTU, specific conductivity ranged from 152–179 µs, and pH ranged from 8–9. From June through August, the water temperature ranged from 12–15 ºC, dissolved oxygen ranged from 4–6 mg/L, turbidity averaged at 0 NTU, specific conductivity ranged from 190–269 µs, and pH averaged 8. From September through October the water temperature ranged from 10–14 ºC, dissolved oxygen ranged from 3–6 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 279–327 µs, and pH averaged 6. In November and December, the water temperature ranged from 8–10 ºC, dissolved oxygen averaged 15 mg/L, turbidity averaged 1 NTU, specific conductivity ranged from 279–283 µs, and pH ranged from 6–7.

Water quality data was also collected each month at the Bickleton Bridge (RM 13) stream crossing on the mainstem, since the site retained instream flow throughout the year. From January through May, the water temperature ranged from 4–9 ºC, dissolved oxygen ranged from 9–13 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 92–108 µs, and pH ranged from 8–9. From June through August, the water temperature ranged from 14–22 ºC, dissolved oxygen ranged from 8-9 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 138–192 µs, and pH averaged 7. From September through October, the water temperature ranged from 14–17 ºC, dissolved oxygen averaged 8 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 203–207 µs, and pH averaged 7. In November and December, the water temperature ranged from 4.5 (November)–11(December) ºC, dissolved oxygen averaged 10 mg/L, turbidity averaged 1 NTU, specific conductivity ranged from 152–192 µs, and pH averaged 7.

Squaw Creek turned intermittent with limited to no instream flow beginning in July, lasting through October. The monitoring site completely dried in July, and no data was collected till the next fall at RM 1. From January through May, the water temperature ranged from 6–10 ºC, dissolved oxygen ranged from 9–13 mg/L, turbidity ranged from 5–10 NTU (with 10 NTU occurring during April – high snow melt), specific conductivity ranged from 126–164 µs, and pH ranged from 8-9. From June through July, the water temperature ranged from 15–23 ºC, dissolved oxygen averaged 11 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 178–244 µs, and pH ranged from 8–9. No water quality data was collected from August through September, since the monitoring site dried up each year.

The Site II water quality site is in lower mainstem Rock Creek (RM 5). From January through May, the water temperature ranged from 5–11 ºC, dissolved oxygen ranged from 10–12 mg/L, turbidity ranged from 5–10 NTU, specific conductivity ranged from 107–121 µs, and pH ranged from 8–9. From June through August, the water temperature ranged from 16–26 ºC, dissolved oxygen ranged from 3–5 mg/L, turbidity averaged at 0 NTU, specific conductivity ranged from 173–210 µs, and pH ranged from 7–8. From September through October, no water quality readings were collected because the monitoring site became dry. In November and December, the water temperature collected ranged from 8–14 ºC, dissolved oxygen averaged 8 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 196–227 µs, and pH ranged from 7–8.

The Army Corps of Engineers Park site (RM 1.3) is the water quality monitoring site lowest in Rock Creek near the inundated pool. This site turned dry in the summer months from July through October each year. From January through June, the water temperature ranged from 6–12 ºC, dissolved oxygen ranged from 11–12 mg/L, turbidity ranged from 0–5 NTU, specific conductivity ranged from 118–161 µs, and pH ranged from 8–9. From July through October, no water quality readings were collected because each year the monitoring site became dry. In November and December, the water temperature collected ranged from 8–16 ºC, dissolved oxygen averaged 8 mg/L, turbidity averaged 0 NTU, specific conductivity ranged from 194–227 µs, and pH averaged 7.

Annual water availability is the limiting factor affecting water quality in all reaches of Rock Creek and its tributary streams. Six out of 8 monitoring sites turned completely dry each summer causing fish stranding or migration to larger pools. Dissolved oxygen levels seemed to be in the normal ranges when there was adequate instream flow, and were lower during the summer months when instream flows became limited and large numbers of fish aggregated in the pools. pH levels seemed to be in the normal range at all sites throughout the year. Turbidity levels were high only during the winter and spring months when there were rain-on-snow melting events in the watershed; the remainder of the year, turbidity was low.

Summaries of water temperature data for each location are presented in Appendix C (Table C-1). Water quality and temperature data were incorporated into the EDT Stream Reach Editor (SRE). Water quality measurements were dependent on the presence of actual instream flow, and therefore not recorded if there was no instream flow at the time of monthly site visit.

A 16°C limit for surface water has been set by the Washington Department of Ecology as an indicator of stream health for salmonid habitat and a 20°C limit for non-salmonid habitat (Washington Department of Ecology, Chapter 173-201A, *Water Quality Standards for the Surface Waters of the State of Washington*). Rock Creek subbasin water temperatures exceeded 16°C at all of the sites during 2008–2013 monitoring years. Water temperature at 6 of 8 sites exceeded 20°C, primarily during the summer months (June through September) illustrated in Table C-1 in Appendix C. Luna Creek (RM 5.2) and Newell Spring (RM 0.2) were the two locations sampled that retained minimal instream flows through the summer and did not exceed 20°C. The Luna Creek monitoring site had the lowest summer stream temperatures out of all the sites, with average maximum water temperatureranges ranging from 14°C to 16°C. Newell Spring contributes very important year-round instream flow to Squaw Creek, especially during the summer months when sections of Squaw Creek become intermittent. The Longhouse (RM 2.2) monitoring site frequently exceeded 25°C during the months of July through September.

We attempted to keep all Hobo water temperature units in the stream year-round; however, some of the units were occasionally washed on shore or lost during high flow events, stolen, or recorded air temperature in pools that had dried up.

During each summer month, intermittency in Rock Creek progresses, forcing juvenile salmonids and other fish species to aggregate in larger pools. Many pools go completely dry during the later summer months, leaving fragmented summer rearing habitat and causing salmonid mortality. In response to elevated stream temperatures, steelhead reduce their foraging and agonistic activity (Sloat and Osterback, 2013). Persistent summer pools in Rock Creek are found in well shaded reaches in the watershed and where there is groundwater connectivity to the stream channel. Upper reaches of Rock, Quartz, and Squaw creeks have perennial flow, and the water temperature are well below the Washington Department of Ecology's 16°C surface water limit. Downstream of the perennial flow sections are reaches with little to no stream cover or shade that annually turn intermittent.

Restoration efforts have been initiated by this project and the Eastern Klickitat Conservation District (EKCD) to improve water temperature in Rock Creek. In 2008, Yakama Nation began implementing a riparian planting project, and each year thereafter has continued the restoration efforts in the lower mainstem Rock Creek. In recent years, EKCD started conducting spring restoration projects in Rock Creek and riparian plantings in upper Squaw Creek. Stream temperatures may be improved through the combined restoration efforts of all interested parties, including private landowners, for the benefit of steelhead abundance and productivity.

2. EDT Modeling

Report C: Assessment of the Rock Creek Watershed Using the Ecosystem Diagnosis and Treatment Model

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June 2014

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Introduction

Salmon habitat models provide managers the ability to identify habitat limitations and prioritize restoration activities. Ecosystem Diagnosis and Treatment (EDT) has become a widely used tool for salmonid habitat analysis in the Pacific Northwest. The EDT model is a rule-based habitat rating system that provides reach-level diagnosis of habitat conditions for the major salmonid species. The EDT process itself is a complex modeling program with defined data needs. The program is a product developed by Mobrand Biometrics Incorporated (MBI, now a subsidiary of ICF International) largely through funding by the Northwest Power and Conservation Council (NPCC). The NPCC has made a chiefly free version of the program accessible through a website that requires user registration (http://www.edt.icfi.com/edt/).

The EDT model allows the user to rate the quality, quantity, and diversity of fish habitat along a waterway. The model uses diagnostic fish species to identify the most significant limiting factors in a river and to help identify and prioritize reaches for protection and restoration actions. The model includes a set of tools with which to organize environmental information and rate the habitat elements that pertain to specific life stages of the diagnostic species. One benefit of EDT is that it can show the potential of a river under current conditions and possible future conditions. The result is a scientifically-based assessment of fish habitat and a prioritization of restoration needs. A strength of the model is its relevancy to population viability criteria (McElhany et al. 2000). The EDT model addresses most of the Viable Salmonid Population (VSP) parameters, which include productivity, abundance, diversity, and spatial structure.

The model rates the quality of river habitat based on salmonid life histories. It uses rating curves to relate habitat conditions to life stage survival and capacity. These life stages are then connected to form life-history trajectories (or the path of a fish through its migratory course). Because habitat is described by reach (homogeneous sections of the river) and over the course of the year (several attributes such as flow, turbidity, and temperature are rated monthly), many potential trajectories can be formed. All successful trajectories are combined to estimate capacity and productivity at a population level. The range of successful trajectories is a measure of life-history diversity.

Each reach of the river has an estimated number of fish or “capacity” that can be supported for each life stage, depending on the quantity of key habitat; a certain amount of food or spawning area is available in the riffles, and the pools can support a quantifiable number of juveniles. Each pool or riffle has characteristics that affect the survival of a life stage in that habitat. The quantity of habitat is thus measured as capacity. When capacity and survival over the course of a fish’s life history is integrated, an overall capacity for the diagnostic species as a measure of the quantity of habitat can be estimated. The number of adult fish that return for each fish that spawns is a gauge of overall survival. This is termed productivity and is a measure of habitat quality.

The model can identify the potential of a river under historical conditions (prior to 1850), current conditions, and scenarios that might occur in the future. The result is an assessment of current conditions and a prioritization of restoration needs. Since each reach is rated separately, conditions can be critically examined along a river from the perspective of the diagnostic species. By comparing the current conditions in each reach with historic conditions, the model identifies the "restoration potential" and the "protection value" for each reach. The model output should help prioritize actions that are focused on areas with identified problems where the potential for benefit is highest.

The model incorporates 46 environmental attributes (termed Level 2 attributes) reported to affect fish survival (Table C-1). A wide variety of information sources (termed Level 1 data) are used to rate the Level 2 attributes. Guidelines for rating the Level 2 attributes are available from the EDT website (http://www.edt.icfi.com/edt/mbi/downloads/all_docs_download.htm). Each attribute is rated for each reach using current (termed "patient") and historic (termed "template") conditions. Level 2 attribute scores are then combined by EDT through a set of rules, based on extensive literature reviews, into relative survivals for 16 Level 3 attributes. The rules used to combine Level 2 attributes into Level 3 relative survivals vary by life stage of the fish.

Table C-1. Organization of Level 2 Environmental Attributes by categories of major stream corridor features. Salmonid Survival Factors (Level 3) are shown associated with groups of Level 2 attributes. Associations can differ by species and life stage. (Lestelle et. al 2004).

Environmental Correlates (Level 2)		Related Survival Factors (Level 3)
1 Hydrologic characteristics		
1.1 Flow variation	Flow - change in interannual variability in high flows	Flow Withdrawals (entrainment)
	Flow - change in interannual variability in low flows	
	Flow - intra daily (diel) variation	
	Flow - intra-annual flow pattern	
	Water withdrawals	
1.2 Hydrologic regime	Hydrologic regime - natural	
	Hydrologic regime - regulated	
2 Stream corridor structure		
2.1 Channel morphometry	Channel length	Channel length Channel stability Channel width Habitat diversity Key habitat Obstructions Sediment load
	Channel width - month maximum width	
	Channel width - month minimum width	
	Gradient	
2.2 Confinement	Confinement - hydromodifications	
	Confinement – natural	
2.3 Habitat type	Habitat type - backwater pools	
	Habitat type - beaver ponds	
	Habitat type – glides	
	Habitat type - large cobble/boulder riffles	
	Habitat type - off-channel habitat factor	
	Habitat type - pool tailouts	
	Habitat type - primary pools	
	Habitat type - small cobble/gravel riffles	
2.4 Obstruction	Obstructions to fish migration	

Environmental Correlates (Level 2)		Related Survival Factors (Level 3)
2.5 Riparian and channel integrity	Bed scour	
	Icing	
	Riparian function	
	Wood	
2.6 Sediment type	Embeddedness	
	Fine sediment (intragravel)	
	Turbidity (suspended sediment)	
3 Water quality		
3.1 Chemistry	Alkalinity	Chemicals (toxic substances) Oxygen Temperature
	Dissolved oxygen	
	Metals - in water column	
	Metals/Pollutants - in sediments/soils	
	Miscellaneous toxic pollutants - water column	
	Nutrient enrichment	
3.2 Temperature variation	Temperature - daily maximum (by month)	
	Temperature - daily minimum (by month)	
	Temperature - spatial variation	
4 Biological community		
4.1 Community effects	Fish community richness	Competition with hatchery fish Competition with other fish Food Harassment Pathogens Predation
	Fish pathogens	
	Fish species introductions	
	Harassment	
	Hatchery fish outplants	
	Predation risk	
	Salmonid carcasses	
4.2 Macroinvertebrates	Benthos diversity and production	

This report details the information used to populate the EDT model, and the results of the model run, for Rock Creek up to the uppermost estimated historic distribution of the diagnostic species (steelhead trout *Oncorhynchus mykiss*). A model run for a single scenario generates a large number of output graphs for each diagnostic species. Therefore, example outputs are presented in this document, but not the full set of outputs. The entire set of outputs are available for download on the EDT website (http://www.edt.icfi.com/edt).

While the principal “product” of the modeling effort was a dataset populated with the best available information to be used for planning future restoration scenarios, the task also enabled us to gather and condense information known about the watershed into a standardized format, which was used to populate the EDT attributes. Included in Appendix A of this report is a summary of the biological data used for each diagnostic species and the rationale and data sources used for each attribute.

Model inputs

Many types of information that had potential to be used to characterize the Rock Creek watershed were identified from many sources, gathered, and organized. Written resources with Level 1 information that could potentially be useful to rate the EDT attributes were collected. The reference materials were then reviewed by USGS and YN personnel for information to be used to rate the Level 2 attributes. Other sources of information such as unpublished Central Klickitat Conservation District (CKCD) temperature data or USGS flow data were included in model inputs.

Reach breaks (to separate the river into “environmentally homogenous” sections; Table C-2) and spawning distributions for the diagnostic fish species (Table C-3) were established during meetings with YN and USGS. The task of defining reaches for an EDT analysis has three parts: defining the geographic scope, describing “environmentally homogeneous” reaches, and coding the hydrography of the basin – *viz.*, indicating the direction of water flow and the spatial relationship of tributaries such that they can be “understood” by a computer program (Mobrand 2002). When defining reaches, there was a need to balance the number of reaches with the resolution of available data and the ability to interpret reach-based results. There are several reaches, RC2, RC3, SQ1, and RC4 in particular, that contain substantial spatial diversity within them. These reaches had short sections with differences in the hydroperiod and proportion of perennial pool habitat. Some sections within these reaches go dry, while other sections had perennial pools and wet riffles. We chose to lump these reaches, rather than split them into many sub-reaches. This allowed us to keep the number of reaches manageable and allowed for a more coherent interpretation of model results. The resolution of available data would not have made the splitting of reaches into a finer scale meaningful. This variability within some reaches needs to be kept in mind during the interpretation of the reach results.

Table C-2. Rock Creek EDT reach and geographic area descriptions and lengths.

Reach Name	Description	River Miles	Length (Mi)	Geographic Area (River Miles)
RC1	Rock Cr. mouth to end of John Day Pool influence	(RM 0 - 1.1)	1.1	Columbia Mainstem
RC2	Rock Cr. end of pool to Old Highway 8	(RM 1.1 - 4.0)	2.9	Rock Cr. below Squaw Cr.
RC3	Rock Cr. Highway 8 to Squaw Cr.	(RM4.0-8.1)	4.1	
SQ1	Squaw Cr. mouth to Harrison Cr.	(RM 0 - 4.5)	4.5	Squaw Cr.
SQ2	Squaw Cr. Harrison Cr.to White Cr.	(RM 4.5- 7.2)	2.9	
RC4	Rock Cr. Squaw Cr. to Luna Gulch	(RM 8.1 - 11.4)	3.1	Rock between Squaw and Luna
LG1	Luna Gulch mouth to end of distribution	(RM 0 - 2.2)	2.2	Luna Gulch
RC6	Rock Cr. Luna Gulch to Badger Gulch	(RM 11.4 - 13.6)	2.1	Rock between Luna and Quartz Cr.
BG1	Badger Gulch mouth to end of distribution	(RM 0 - 0.5)	0.5	
RC7	Rock Cr. Badger Gulch to Unnamed Trib	(RM 13.6 - 14.7)	1.1	
RC8	Rock Cr. Unnamed Trib to Quartz Cr.	(RM 14.7 - 17.3)	2.7	
QZ1	Quartz Cr. mouth to small slide	(RM 0 - 2.4)	2.4	Quartz Cr.
QZ2	Quartz Cr. small slide at RM 2.4	Obstruction	0	
QZ3	Quartz Cr. small slide to Box Canyon Cr.	(RM 2.4 - 3.0)	0.55	
BX1	Box Cr. mouth to end of distribution	(RM 0 - 0.3)	0.3	
QZ4	Quartz Cr. Box Canyon Cr. to end of distribution	(RM 3.0 - 3.8)	0.8	
RC9	Rock Cr. Quartz Cr. to small falls	(RM 17.3 - 18.6)	1.3	Rock above Quartz Cr.
RC10	Rock Cr. small waterfall at RM 18.6	Obstruction	0	
RC11	Rock Cr. small waterfall to super slide	(RM 18.6- 20.3)	1.7	
RC12	Rock Cr. Super Slide at RM 20.3 (Ekone)	Obstruction	0	

Table C-3. Registered steelhead age structure, spawning reaches and timing, harvest pattern, and migration patterns for the Rock Creek EDT model. Downloaded from the EDT Online Fish Population Editor on April 30 2014. (http://www.edt.icfi.com/edt/)

Population Name:	**Rock Creek Steelhead**		
Population Description:	**Rock Creek Steelhead**		
Stream Reach Dataset:	**Rock Creek revised 2014**		
Species:	**Summer Steelhead**		
Spawning Reaches:	**Mainstem Reaches:**	**Tributary Reaches:**	
	RC2	**SQ1**	
	RC3	**SQ2**	
	RC4	**LG1**	
	RC6	**BG1**	
	RC7	**QZ1**	
	RC8	**QZ2-obstr.**	
	RC9	**QZ3**	
	RC10-obstr.	**BX1**	
	RC11	**QZ4**	
First Week of Spawning:	**February 26 – March 4**		
Last Week of Spawning:	**April 23 - April 29**		
Harvest Pattern:	**Summer Steelhead**		

Migration Pattern	**Percent**	**Adult Age**	**Juvenile Age**
Rock Cr. Summer Steelhead – Resident	30%	Rock Cr. Summer Steelhead	**Rock Cr. Summer Steelhead**
Rock Cr. Summer Steelhead – Transient	70%	Rock Cr. Summer Steelhead	**Rock Cr. Summer Steelhead**
Combined percentage:	**100 %**	**(Combined percentage must total 100%)**	

The geographic scope was defined as the locations in Rock Creek that were expected to be historically and currently accessible by steelhead or their progeny. The reach breaks were defined based upon the locations of tributary junctions, changes in confinement, and potential fish barriers. In all, there were 12 reaches in the mainstem Rock Creek and 9 reaches in the tributaries (Table C-2). While tributary junctions and obstructions were easily identifiable, establishing a reach break based on changes in confinement was more subjective.

Barriers in Rock Creek at river mile 18.6 and Quartz Creek at river mile 2.4, which are natural waterfalls, were attributed a 100 percent passage rating during the winter months, transitioning to 0 percent passage during the summer and fall months (due to low flow). Further investigation of these waterfalls would allow for a more accurate passage rating and fish distribution.

A single diagnostic fish species (steelhead) was selected from the limited array of anadromous salmonids that would have historically inhabited Rock Creek (Table C-3). Other species such as coho salmon were considered, since juvenile coho were found in 2011 during electrofishing surveys by USGS and the YN. Coho were not incorporated into the Rock Creek EDT diagnostic fish species list; however, because there does not appear to be a viable population in Rock Creek. Fall Chinook salmon have been found during spawning surveys in some years, but were not included in this modeling effort either, as they also do not likely have a viable population in Rock Creek.

Historical and current spawning distributions were estimated based on spawning surveys, the life history and swimming/jumping ability of steelhead, and our estimates of the historic channel condition in the reach of interest. Spawning distribution for the registered fish population (steelhead trout) is shown in Table C-3, and was downloaded from MBI's EDT Online Fish Population Editor on 15 April 2014. A population definition consists of the age structure and spawning, harvest, and migration patterns of a species (Table C-3). Although harvesting of wild summer steelhead does occur in the mainstem of the Columbia River, the harvest pattern for the model was rated as 0 percent (Greg Blair, ICFI, personal communication). The Yakama Nation watershed administrator collaborated with MBI to establish the diagnostic fish species population definitions.

As of May 2014, the EDT dataset for Rock Creek has been populated and the model has been run. The dataset that YN collaborated with USGS to produce, titled "Rock Cr. revised 5-6-14", describes Rock Creek in the "patient" dataset as it currently exists and the "template" dataset as we think Rock Creek existed prior to European settlement. Appendix A describes the rationales and information used to populate the variables included in the model. We will present and discuss the results of the registered dataset below, and these results are available to download via the website. As of this writing, the "Rock Cr. revised 5-6-14" dataset is registered on the EDT website and any changes to the model have to go through the watershed administrator (Elaine Harvey).

Model outputs

Because of the complexity of the model, a full description of all the reach results by diagnostic species is beyond the scope of this document; however, example outputs from key reaches are presented and explained below. The full output report can be downloaded at: http://www.edt.icfi.com/edt/

Baseline outputs

After the reaches for Rock Creek had been established and portrayed in terms of Level 2 attributes, a model run of the dataset was conducted. There are several reports or outputs generated from a model run. One of the coarse-scale baseline outputs, termed "report 1", includes results for both smolts and adults. The report 1 output is displayed in the form of the population performance parameters, described in the introduction (productivity, capacity, equilibrium abundance, and life history diversity), for the "patient", the "template" conditions of the scenario describing the watershed.

Table C-4 summarizes the "report 1" outputs for adults and smolts from the historic potential ("template") condition, and the "patient" conditions titled "current without harvest". Essentially, the population performance parameters improve as the modeled conditions change from the "current without harvest", to "historic potential". The historic potential abundance of steelhead in Rock Creek is seven times greater than what current conditions are modeled to be.

Table C-4. “Report 1” – A summary of baseline adult spawner and juvenile outmigrant population performance parameters (diversity, productivity, capacity and abundance) for historic potential and current conditions.

Population	Scenario	Diversity index (%)	Productivity	Capacity	Abundance
Rock Creek steelhead adult spawner	Current without harvest	42	1.5	92	29
	Historic potential	80	3.0	286	190
Rock Creek steelhead juvenile outmigrant	Current without harvest	-	72	4,726	1,453
	Historic potential	-	142	15,385	9,808

While these estimates have some meaning, their main value is in troubleshooting by determining the “reasonableness” of the outcome and therefore appropriateness of the way the populations and their habitat have been described. One should keep in mind that EDT outputs represent an equilibrium state, representing average habitat and climate conditions. The EDT productivity parameter is an estimated maximum productivity for average environmental conditions, therefore observed productivity should be notably less. This is also true for the capacity parameter. Therefore, abundance is the most appropriate performance parameter for assessing output accuracy, because it integrates productivity and capacity (Mobrand 2002). In other basins within the Columbia River Gorge Province, the EDT-predicted estimates of smolt and/or adult performance have been reasonably close to empirical estimates from WDFW population estimates (Rawding 2004). However, none of these basins were intermittent to the extent that Rock Creek is, and model performance has not been validated for intermittent stream types.

The lack of long-term assessment of anadromous fish abundance in Rock Creek makes it difficult to assess the “reasonableness” of the outcome. Nonetheless, we can provide a rough estimate of the total number of juvenile outmigrants in 2011 and 2012 to compare with the EDT model estimates. In 2011 and 2012, USGS and the YN conducted juvenile fish population estimates and obtained the abundance of age-1 steelhead per square meter in a subset of randomly selected pools. Averaged across all pools, Rock Creek abundance ranged from 0.17 to 0.25 fish per square meter and Squaw Creek abundance ranged from 0.25 to 1.51 fish per meter squared. Along with this effort, we assessed the surface area of late summer perennial pools in Rock Creek downstream of Bickleton Bridge and in Squaw Creek from the confluence to 1 mile upstream of Harrison Creek. The surface area of pools ranged from 25,136 square meters in 2012 to 35,211 square meters in 2010. We also estimated the proportion of PIT-tagged fish that survived and outmigrated to be 24 percent, using PIT-tag detectors at river kilometer 5 and PIT-tag detections in the Columbia River. Using these numbers we generated estimates of juvenile outmigration ranging from 1,545 in 2012 to 2,785 in 2011. These estimates would be less than the total number of outmigrants as it did not include any juvenile production from upstream of Bickleton Bridge, including Quartz Creek. In comparison to these rough calculations of the number of juvenile outmigrants, we believe the performance of steelhead in the basin predicted by the EDT model is reasonable, but low.

Diagnostic outputs

Geographic area priorities

An EDT model run produces outputs with information specific to each diagnostic fish species for each reach. These outputs are referred to as the reach-scale and/or geographic area-scale analyses, termed “report 2”. The geographic area scale essentially lumps individual reaches into a user-specified geographic area for ease of presentation. In Rock Creek, each tributary was designated as a separate geographic area as well as similar mainstem sections (Table C-3, Figure C-1). Reach-scale analysis takes into account the same salmonid population performance parameters as the baseline output, but it provides a greater level of detail by identifying reaches based on their relative protection and restoration value.

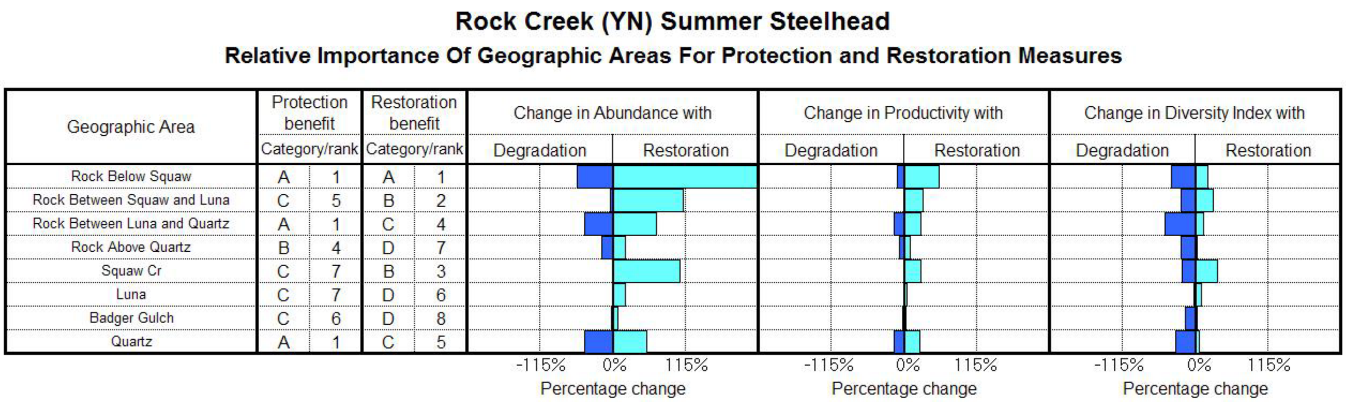

Figure C-1. The relative restoration and preservation ranking and value of geographic areas in Rock Creek based on EDT population performance parameters of steelhead. The registered dataset (Rock Cr. revised 5-6-14) was used to generate this output.

One of the outputs from the report 2 analyses is called the “tornado” or “ladder” diagram (Figure C-1). The tornado diagram lists reaches that can be prioritized by “protection benefit” and “restoration benefit”. Protection benefit is the degree to which the performance parameters of a population are supported by a specific reach or geographic area. In other words, protection benefit indicates the estimated reduction in population performance if that reach or geographic area’s habitat conditions worsened. Restoration potential is the increase in performance a population would experience if a single reach or geographic area were restored to historical conditions (Mobrand 2004).

The model can sort the reaches in the tornado diagrams by ranking the reaches’ importance to the diagnostic species averaged across all performance parameters (Figure C-1). This report helps display where protection and restoration efforts would benefit the diagnostic species the most. The Rock Cr. below Squaw Cr. reach has relatively high restoration and high preservation potential. Although this may seem contradictory, it actually indicates that this reach has potential to be more productive, and has a larger effect on population performance than other reaches with less restoration or preservation benefit. The diagrams include reach length when ranking, so consideration should be taken that longer reaches may inherently be ranked higher. Also, areas lower in the mainstem have the most life history trajectories through them, and are therefore inherently ranked higher for both restoration and preservation benefit. In the geographic area downstream of Squaw Creek, (RC2 and RC3), several habitat features are lumped together in the model, such as water table depth at low flow, that would need to be assessed at a finer scale prior to any restoration actions. Furthermore, it may be impossible to restore some attributes, such as water temperature, to the historic condition given current conditions and predicted climate change. Therefore, portions of RC2 and RC3 may not warrant restoration actions, because desired historic conditions would not be attainable. It is possible that restoration actions in this geographic area could encourage more fish to rear there, and if temperature or water depth became unsuitable, the attempted restoration could do more harm than good.

Habitat factor analysis - Geographic area summary

The "consumer report diagrams" display the habitat factors or Level 3 survival factors that affect production potential. The level 2 attributes that are used to rate the Level 3 survival factors are listed in Table C-1, and Table C-5 contains definitions for each survival factor. There are several types of consumer reports that are standard model outputs. One report, titled "Protection and restoration strategic priority summary", shows the level of reduced productivity summarized by the habitat factors across the same set of reaches or geographic areas as the tornado diagrams presented above (Figure C-2). This output condenses the most influential habitat factors across all life stages, and in the case of a geographic area-analysis, across a number of reaches. This report is a display of the habitat factors that most reduce the diagnostic species' population performance.

Table C-5. Definitions for the habitat factors or Level 3 survival factors (Lestelle et. al 2004).

Factor	Definition
Channel stability	The effect of stream channel stability (within reach) on the relative survival or performance of the focus species; the extent of channel stability is with respect to its streambed, banks, and its channel shape and location.
Chemicals	The effect of toxic substances or toxic conditions on the relative survival or performance of the focus species. Substances include chemicals and heavy metals. Toxic conditions include low pH.
Competition (with hatchery fish)	The effect of competition with hatchery produced animals on the relative survival or performance of the focus species; competition might be for food or space within the stream reach.
Competition (with other species)	The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space.
Flow	The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species. Effects of flow reductions or dewatering due to water withdrawals are to be included as part of this attribute.
Food	The effect of the amount, diversity, and availability of food that can support the focus species relative survival or performance.

Factor	Definition
Habitat diversity	The effect of the extent of habitat complexity within a stream reach on the relative survival or performance of the focus species.
Harassment	The effect of harassment, poaching, or non-directed harvest (i.e., as can occur through hook and release) on the relative survival or performance of the focus species.
Key habitat	The relative quantity of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel.
Obstructions	The effect of physical structures impeding movement of the focus species on its relative survival or performance within a stream reach; structures include dams and waterfalls.
Oxygen	The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species.
Pathogens	The effect of pathogens within the stream reach on the relative survival or performance of the focus species. The life stage when infection occurs is when this effect is accounted for.
Predation	The effect of the relative abundance of predator species on the relative survival or performance of the focus species.
Sediment load	The effect of the amount of the amount of fine sediment present in, or passing through, the stream reach on the relative survival or performance of the focus species.
Temperature	The effect of water temperature with the stream reach on the relative survival or performance of the focus species.
Withdrawals (or entrainment)	The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survival or performance of the focus species. This effect does not include dewatering due to water withdrawals, which is covered by the flow attribute.

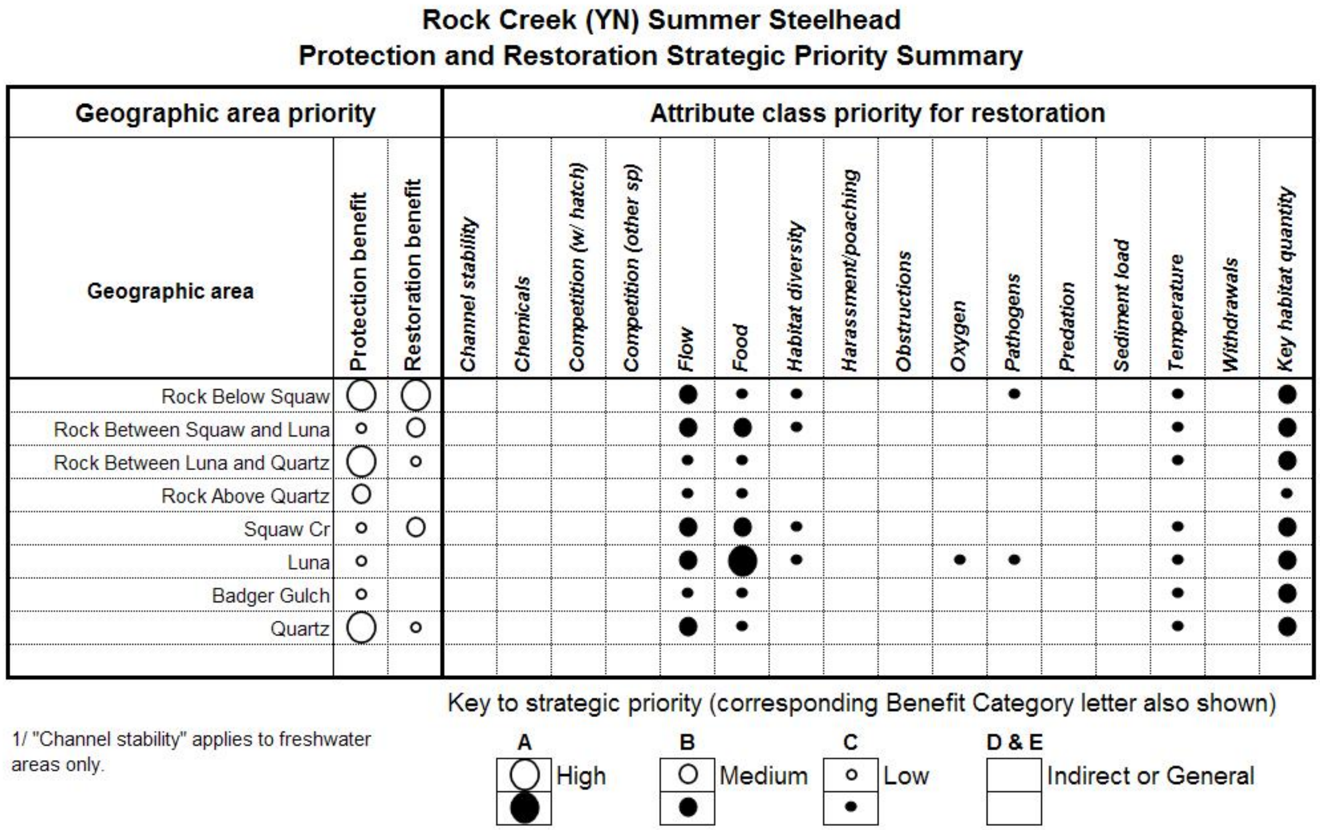

Figure C-2. The habitat factor analysis diagram of Rock Creek averaged across all life stages of steelhead.

Key habitat quantity and stream flow are attributes that limit the population in nearly every reach. Key habitat varies by life stage and is further explained in the reach summaries described below. Food availability and (to a lesser extent) temperature also limit the steelhead population in nearly every reach. Increasing stream flow would likely improve food availaibility and stream temperature.

Habitat factor analysis – Life stage summary

Another type of consumer report summarizes the loss in productivity by life stage across all reaches. Table C-6 defines the life stages of steelhead and Figure C-3 describes the loss in productivity for each life stage, and ranks the life stages by those that are most affected.

Table C-6. Description of steelhead life stages within the freshwater environment (Lestelle et. al 2004).

Life stage	Description
Spawning	Period of active spawning, beginning when fish move on to spawning beds and initiate redd digging and ending when gametes are released. Note: For computational purposes, the reproductive potential associated with a spawning female is incorporated at the beginning of this stage; this potential includes sex ratio (average females per total spawners) and average fecundity per female.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of the release of gametes by spawners and ends at fry emergence (losses to egg viability that occur in the instant prior to fertilization are included here).
Fry colonization	Fry emergence and initial dispersal; time period is typically very short, beginning at fry emergence and ending when fry begin active feeding associated with a key habitat.
0-age resident/active rearing	Rearing by age 0 fish that is largely associated with a small "home range"; these fish are generally territorial.
0-age migrant	Directional migration by age 0 fish that tends to be rapid and not strongly associated with feeding/rearing. This type of movement typically occurs when fish redistribute within the stream system prior to, or during, winter.
0-age inactive	Largely inactive or semi-dormant age 0 fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
1-age resident/active rearing	Feeding/rearing by age 1 fish that is associated with a home range; these fish are often territorial.
1-age migrant	Directional migration by age 1 fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
1-age inactive	Largely inactive or semi-dormant fish age 1fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
2+-age resident rearing	Feeding/rearing by age 2 and older fish that is associated with a home range; these fish are often territorial.
2+-age migrant	Directional migration by age 2 fish that tends to be rapid and not strongly associated with feeding/rearing. Such migrations will typically occur during either spring or fall/early winter by fish migrating seaward or as redistribution to a different freshwater habitat (such as occurs following winter or in preparation for winter).
2+-age inactive	Largely inactive or semi-dormant fish age 2 and older fish; this behavior is associated with overwintering, when feeding is reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
Migrant prespawner	Adult fish approaching sexual maturity that are migrating to their natal stream; in the ocean this stage occurs in the final year of marine life, in freshwater feeding has generally ceased.
Holding prespawner	Adult fish approaching sexual maturity that are largely stationary and holding, while en-route to their spawning grounds; distance to the spawning grounds from holding sites may be short or long.

Rock Creek (YN) Summer Steelhead
Life Stage Summary Across All Geographic Areas

Life stage	Relevant months	Productivity change (%)	Life Stage Rank	Change in attribute impact on survival: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	-0.9%	8							• Small									
Egg incubation	Mar-Jun	-1.6%	7	• Small													• Small		● Moderate
Fry colonization	Apr-Jul	-11.0%	4	• Small				• Small	⬤ High	• Small							• Small		⬤ High
0-age active rearing	May-Oct	-35.3%	1			• Small		⬤ High	● Moderate	• Small				• Small	• Small		● Moderate		⬤ High
0,1-age inactive	Oct-Mar	-14.7%	3	• Small				• Small	● Moderate	• Small									● Moderate
1-age migrant	Mar-Jun	-0.3%	10							• Small									● Moderate
1-age active rearing	Mar-Oct	-11.4%	3			• Small		• Small	● Moderate	• Small							• Small		● Moderate
2+-age active rearing	Mar-Oct	-6.5%	6																● Moderate
2+-age migrant	Mar-Jun	-0.1%	14							• Small									● Moderate
2+-age transient rearing	Jan-Dec	0.0%	15																
Prespawning migrant	Jun-Feb	-0.1%	12																• Small
Prespawning holding	Sep-Apr	-0.1%	11																⬤ High

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY NA = Not applicable

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-3. The summary of changes in productivity by life stage, averaged across all geographic areas of Rock Creek.

The life stage with the greatest loss in productivity is age-0 active rearing, which is affected by the low summer flow conditions in Rock Creek. Stream flow and key habitat quantity are the attributes that reduce survival of the age-0 active rearing life stage the most. As the stream flow becomes subsurface and the water table drops throughout the summer, the perennial pool surface area shrinks and some pools go completely dry, causing age-0 steelhead abundance to be reduced by 35 percent compared to historic conditions. Age-0, 1 inactive, age-1 inactive, and fry colonization life stages are essentially tied as the life stages with the next greatest loss in productivity when averaged across all reaches.

Reach analysis

The last type of consumer report diagram, titled “Reach analysis”, provides the most detail, by describing the Level 3 survival factors influence on the survival of each life stage of steelhead, the relevant months, percent of life history trajectories affected, the percent change in productivity, and several other statistics for each individual reach. The reduction in productivity of each life stage as affected by changes in habitat is relative to historic conditions. As with the diagrams above, the size of the black dots in the reach analysis diagrams indicate the relative influence that the habitat attribute has on the survival of each life stage of the diagnostic species. The “percent of the life history trajectories affected" indicates the proportion of each life stage of the total steelhead in Rock Creek that uses that reach. For example, in reach RC2, 100 percent of the prespawn migrants travel in this reach, but only 5.5 percent of the adult steelhead spawn in this reach (Figure 4). Each life stage is also ranked, with 1 representing the life stage with the most severe reduction in survival. Ranking is based on the percent of time a given life stage resides in the reach, as well as the degree to which survival is reduced relative to historical conditions. The definition for each life stage of steelhead is presented in Table C-6.

The reach analysis level of detail can be useful for specific recovery measures in specific reaches. Reach analysis diagrams of the mainstem reaches (Figures C-4, C-5, C-8, C-10 , C-12, C-13, C-18 and C-19, Table C-3) and tributary reaches (Figures C-6, C-7, C-9, C-11, C-14, C-15, C-16, and C-17, Table C-3) are presented for comparison. However, because the reach analysis diagrams are reach specific they may be too detailed to compare habitat problems across the watershed.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Rock Below Squaw	**Stream:**	Rock Cr
Reach:	Rock Cr end of pool to Old Highway 8 (RM 1.1 -4.0)	**Reach Length (mi):**	2.90
		Reach Code:	RC2

Restoration Benefit Category:1/	A	**Productivity Rank:1/**	1	**Potential % change in productivity:2/**	54.7%
Overall Restoration Potential Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**Potential % change in Neq:2/**	228.1%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	3	**Potential % change in diversity:2/**	18.8%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	3	**% loss in productivity with degradation:2/**	-10.1%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**% loss in Neq with degradation:2/**	-55.4%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	2	**% loss in diversity with degradation:2/**	-38.0%

					Change in attribute impact on survival															
Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	5.5%	-1.7%	11							Moderate	Small								Moderate (gain)
Egg incubation	Mar-Jun	5.5%	-3.0%	9	Small													Small		Moderate (gain)
Fry colonization	Apr-Jul	5.5%	-14.1%	5	Moderate			Small	Small	High	Moderate					Small		Moderate		High
0-age active rearing	May-Oct	5.5%	-54.5%	1	Small		Small	Small	High	Small	Moderate				Moderate	Moderate		Moderate		High
0,1-age inactive	Oct-Mar	21.5%	-11.8%	3	Small				Small	Moderate	Small									Moderate
1-age migrant	Mar-Jun	59.7%	-0.5%	7							Small					Small				Moderate
1-age active rearing	Mar-Oct	19.2%	-14.8%	2	Small		Small	Small	Small	Moderate	Small					Small		Moderate		Moderate
2+-age active rearing	Mar-Oct	7.7%	-5.8%	6							Small							Small		Moderate
2+-age migrant	Mar-Jun	45.4%	-0.1%	12							Small									Moderate
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	100.0%	-0.2%	8																Small
Prespawning holding	Sep-Apr	5.5%	-0.3%	14							Small									High
All Stages Combined		100.0%																		

1/ Ranking based on effect over entire geographic area.

2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-4. A steelhead "consumer reports diagram" for reach RC2 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead		***2014 Rock Creek Steelhead EDT Report - Summer Steelhead***
Restoration Potential:	Current Conditions versus Historic Potential		
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories		

Geographic Area:	Rock Below Squaw	**Stream:**	Rock Cr
Reach:	Rock Cr Highway 8 to Squaw Cr (RM 4.0 - 8.1)	**Reach Length (mi):**	4.10
		Reach Code:	RC3

Restoration Benefit Category:1/	A	**Productivity Rank:1/**	1	**Potential % change in productivity:2/**	54.7%
Overall Restoration Potential Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**Potential % change in Neq:2/**	228.1%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	3	**Potential % change in diversity:2/**	18.8%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	3	**% loss in productivity with degradation:2/**	-10.1%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	1	**% loss in Neq with degradation:2/**	-55.4%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	2	**% loss in diversity with degradation:2/**	-38.0%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
					Change in attribute impact on survival															
Spawning	Feb-May	14.3%	-0.9%	11							•	•								○
Egg incubation	Mar-Jun	14.3%	-1.7%	8	•													•		•
Fry colonization	Apr-Jul	15.6%	-6.0%	4	•			•	•	●	•							•		⬤
0-age active rearing	May-Oct	15.6%	-39.7%	1	•		●	•	⬤	•	•				•	•		●		⬤
0,1-age inactive	Oct-Mar	47.2%	-3.9%	4	•				•	•	•									●
1-age migrant	Mar-Jun	62.3%	-0.5%	7							•									⬤
1-age active rearing	Mar-Oct	37.1%	-6.2%	2			•	•	•	•	•							•		⬤
2+-age active rearing	Mar-Oct	19.3%	-1.9%	6																●
2+-age migrant	Mar-Jun	38.0%	-0.1%	12							•									●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	94.5%	-0.2%	10																●
Prespawning holding	Sep-Apr	14.3%	-0.2%	13																⬤
All Stages Combined		94.5%																		

1/ Ranking based on effect over entire geographic area.   2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-5. A steelhead "consumer reports diagram" for reach RC3 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Squaw Cr	**Stream:**	Squaw Cr
Reach:	Squaw Cr mouth to Harrison Cr (RM 0 - 4.5)	**each Length (mi):**	4.50
		Reach Code:	SQ1

Restoration Benefit Category:1/	B	**Productivity Rank:1/**	4	**Potential % change in productivity:2/**	25.9%
Overall Restoration Potential Rank:1/	3	**Average Abundance (Neq) Rank:1/**	3	**Potential % change in Neq:2/**	105.7%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	1	**Potential % change in diversity:2/**	33.7%
Preservation Benefit Category:1/	C	**Productivity Rank:1/**	8	**ss in productivity with degradation:2/**	0.0%
Overall Preservation Rank:1/	7	**Average Abundance (Neq) Rank:1/**	8	**% loss in Neq with degradation:2/**	0.0%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	6	**% loss in diversity with degradation:2/**	-19.9%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival:** Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	14.0%	-1.0%	9							●									⬤
Egg incubation	Mar-Jun	14.0%	-2.9%	6	•													•		⬤
Fry colonization	Apr-Jul	16.4%	-20.6%	2	•			•	•	⬤	●					•		•		⬤
0-age active rearing	May-Oct	14.4%	-37.7%	1	•		•		⬤	●	•				•	•		●		⬤
0,1-age inactive	Oct-Mar	16.5%	-24.7%	3	•				•	⬤	•									●
1-age migrant	Mar-Jun	15.9%	-0.4%	10							•									⬤
1-age active rearing	Mar-Oct	15.6%	-13.3%	4			•		•	●	•							•		●
2+-age active rearing	Mar-Oct	3.4%	-7.4%	7					•											●
2+-age migrant	Mar-Jun	4.1%	-0.1%	14							•									●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	22.9%	-0.1%	11																●
Prespawning holding	Sep-Apr	14.0%	-0.1%	12																●
All Stages Combined		22.9%																		

1/ Ranking based on effect over entire geographic area.

2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width. Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-6. A steelhead "consumer reports diagram" for reach SQ1 of Squaw Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Squaw Cr			**Stream:**	Squaw Cr
Reach:	Squaw Cr Harrison Cr to White Cr (RM 4.5 - 7.2)			**Reach Length (mi):**	2.90
				Reach Code:	SQ2
Restoration Benefit Category:1/	B	**Productivity Rank:1/**	4	**Potential % change in productivity:2/**	25.9%
Overall Restoration Potential Rank:1/	3	**Average Abundance (Neq) Rank:1/**	3	**Potential % change in Neq:2/**	105.7%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	1	**Potential % change in diversity:2/**	33.7%
Preservation Benefit Category:1/	C	**Productivity Rank:1/**	8	**Loss in productivity with degradation:2/**	0.0%
Overall Preservation Rank:1/	7	**Average Abundance (Neq) Rank:1/**	8	**% loss in Neq with degradation:2/**	0.0%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	6	**% loss in diversity with degradation:2/**	-19.9%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
					Change in attribute impact on survival															
Spawning	Feb-May	8.9%	-0.8%	5							•									•
Egg incubation	Mar-Jun	8.9%	-0.4%	7																●
Fry colonization	Apr-Jul	8.9%	-7.4%	2	•				•	●	•					•		•		●
0-age active rearing	May-Oct	6.5%	-24.0%	1					●	•	•				•	•		•		●
0,1-age inactive	Oct-Mar	2.4%	-8.7%	4					•	•	•									●
1-age migrant	Mar-Jun	1.0%	0.0%	10							•									●
1-age active rearing	Mar-Oct	1.7%	-8.0%	4					•	●	•							•		●
2+-age active rearing	Mar-Oct	0.8%	-2.4%	8					•											●
2+-age migrant	Mar-Jun	0.8%	0.0%	10							•									●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	8.9%	0.0%	10																●
Prespawning holding	Sep-Apr	8.9%	-0.1%	9																●
All Stages Combined		8.9%																		

1/ Ranking based on effect over entire geographic area.

2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	○
Moderate	●	○
High	●	○
Extreme	●	○

Figure C-7. A steelhead "consumer reports diagram" for reach SQ2 of Squaw Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead	
Restoration Potential:	Current Conditions versus Historic Potential	***2014 Rock Creek Steelhead EDT***
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories	***Report - Summer Steelhead***

Geographic Area:	Rock Between Squaw and Luna	**Stream:**	Rock Cr
Reach:	Rock Cr Squaw Cr to Luna Gulch (RM 8.1 to 11.4)	**Reach Length (mi):**	3.10
		Reach Code:	RC4

Restoration Benefit Category:1/	B	**Productivity Rank:1/**	2	**Potential % change in productivity:2/**	28.4%
Overall Restoration Potential Rank:1/	2	**Average Abundance (Neq) Rank:1/**	2	**Potential % change in Neq:2/**	109.9%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	2	**Potential % change in diversity:2/**	27.2%
Preservation Benefit Category:1/	C	**Productivity Rank:1/**	6	**% loss in productivity with degradation:2/**	-0.4%
Overall Preservation Rank:1/	5	**Average Abundance (Neq) Rank:1/**	5	**% loss in Neq with degradation:2/**	-3.3%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	4	**% loss in diversity with degradation:2/**	-22.5%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival:** Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	11.7%	-2.0%	8							●									○
Egg incubation	Mar-Jun	11.7%	-2.3%	7	•													•		•
Fry colonization	Apr-Jul	15.2%	-18.4%	4	•			•	●	⬤	●					•		•		⬤
0-age active rearing	May-Oct	15.0%	-41.2%	1	•		•		⬤	●	●				•	•		●		⬤
0,1-age inactive	Oct-Mar	26.4%	-25.2%	3	•				•	●	•									●
1-age migrant	Mar-Jun	35.5%	-0.4%	10							•									●
1-age active rearing	Mar-Oct	22.7%	-14.3%	3			•		•	●	•							•		●
2+-age active rearing	Mar-Oct	7.3%	-7.8%	6					•		•									●
2+-age migrant	Mar-Jun	14.8%	-0.1%	13							•									●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	57.3%	-0.1%	11																•
Prespawning holding	Sep-Apr	11.7%	-0.3%	12																⬤
All Stages Combined		57.3%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-8. A steelhead "consumer reports diagram" for reach RC4 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead		***2014 Rock Creek Steelhead EDT Report - Summer Steelhead***
Restoration Potential:	Current Conditions versus Historic Potential		
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories		

Geographic Area:	Luna	**Stream:**	Luna Gulch Cr
Reach:	Luna Gulch mouth to end of distribution (RM 0 - 2.2)	**Reach Length (mi):**	2.20
		Reach Code:	LG1

Restoration Benefit Category:1/	D	**Productivity Rank:1/**	7	**Potential % change in productivity:2/**	4.0%
Overall Restoration Potential Rank:1/	6	**Average Abundance (Neq) Rank:1/**	7	**Potential % change in Neq:2/**	18.4%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	5	**Potential % change in diversity:2/**	8.7%
Preservation Benefit Category:1/	C	**Productivity Rank:1/**	7	**oss in productivity with degradation:2/**	-0.1%
Overall Preservation Rank:1/	7	**Average Abundance (Neq) Rank:1/**	7	**% loss in Neq with degradation:2/**	-0.8%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	8	**% loss in diversity with degradation:2/**	-1.1%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival**: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	5.9%	-1.0%	8							Moderate									Moderate
Egg incubation	Mar-Jun	5.9%	-2.7%	7	Small													Small		High
Fry colonization	Apr-Jul	5.9%	-48.7%	1	Small			Small	Moderate	Extreme	Moderate			Moderate				Small		High
0-age active rearing	May-Oct	4.0%	-53.0%	2	Small		Small		High	High	Moderate			Moderate	Moderate	Small		Moderate		High
0,1-age inactive	Oct-Mar	1.9%	-100.0%	4	Small				Moderate	Extreme	Moderate									Moderate
1-age migrant	Mar-Jun	1.3%	-0.1%	11							Small									Moderate
1-age active rearing	Mar-Oct	1.6%	-100.0%	3	Small		Small		Moderate	Extreme	Moderate			Small				Small		High
2+-age active rearing	Mar-Oct	0.3%	-100.0%	5					Small		Small									Moderate
2+-age migrant	Mar-Jun	0.3%	0.0%	13							Small									Moderate
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	5.9%	0.0%	12																Moderate
Prespawning holding	Sep-Apr	5.9%	-0.2%	10																High
All Stages Combined		5.9%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY NA = Not applicable

	Loss	Gain
None		
Small	● (small)	○ (small)
Moderate	● (moderate)	○ (moderate)
High	● (high)	○ (high)
Extreme	● (extreme)	○ (extreme)

Figure C-9. A steelhead "consumer reports diagram" for reach LG1 of Luna Gulch Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead		***2014 Rock Creek Steelhead EDT Report - Summer Steelhead***
Restoration Potential:	Current Conditions versus Historic Potential		
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories		

Geographic Area:	Rock Between Luna and Quartz	**Stream:**	Rock Cr
Reach:	Rock Cr Luna Gulch to Badger Gulch (RM 11.4 - 13.6)	**Reach Length (mi):**	2.10
		Reach Code:	RC6

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	3	**Potential % change in productivity:2/**	26.3%
Overall Restoration Potential Rank:1/	4	**Average Abundance (Neq) Rank:1/**	4	**Potential % change in Neq:2/**	67.9%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	4	**Potential % change in diversity:2/**	12.7%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	2	**% loss in productivity with degradation:2/**	-14.8%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	3	**% loss in Neq with degradation:2/**	-43.6%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	1	**% loss in diversity with degradation:2/**	-47.1%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival:** Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	6.5%	-1.0%	6							•						•			○
Egg incubation	Mar-Jun	6.5%	-0.8%	8														•		●
Fry colonization	Apr-Jul	9.5%	-9.9%	2	•			•	•	●	•					•		•		⬤
0-age active rearing	May-Oct	8.4%	-32.9%	1			•		⬤	•	•				•	•		●		⬤
0,1-age inactive	Oct-Mar	5.8%	-13.6%	4					•	●										●
1-age migrant	Mar-Jun	16.1%	0.0%	11							•									●
1-age active rearing	Mar-Oct	5.6%	-8.9%	4			•		•	●	•							•		●
2+-age active rearing	Mar-Oct	1.5%	-4.1%	7					•											●
2+-age migrant	Mar-Jun	7.2%	0.0%	12																●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	39.8%	-0.1%	9																•
Prespawning holding	Sep-Apr	6.5%	-0.2%	10																●
All Stages Combined		39.8%																		

1/ Ranking based on effect over entire geographic area.   2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-10. A steelhead "consumer reports diagram" for reach RC6 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead		***2014 Rock Creek Steelhead EDT Report - Summer Steelhead***
Restoration Potential:	Current Conditions versus Historic Potential		
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories		

Geographic Area:	Badger Gulch			**Stream:**	Badger Gulch Cr
Reach:	Badger Gulch mouth to end of distribution (RM 0 - 0.5)			**Reach Length (mi):**	0.50
				Reach Code:	BG1
Restoration Benefit Category:1/	D	**Productivity Rank:1/**	8	**Potential % change in productivity:2/**	2.0%
Overall Restoration Potential Rank:1/	8	**Average Abundance (Neq) Rank:1/**	8	**Potential % change in Neq:2/**	6.3%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	7	**Potential % change in diversity:2/**	2.2%
Preservation Benefit Category:1/	C	**Productivity Rank:1/**	5	**% loss in productivity with degradation:2/**	-1.2%
Overall Preservation Rank:1/	6	**Average Abundance (Neq) Rank:1/**	6	**% loss in Neq with degradation:2/**	-1.8%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	7	**% loss in diversity with degradation:2/**	-14.9%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival**															
					Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	1.4%	-1.1%	8							•						•			●
Egg incubation	Mar-Jun	1.4%	-0.8%	9														•		⬤
Fry colonization	Apr-Jul	2.0%	-5.9%	4					•	●	•							•		⬤
0-age active rearing	May-Oct	1.5%	-23.6%	1			•		●	•	•				•			●		⬤
0,1-age inactive	Oct-Mar	3.8%	-7.2%	2					•	●	•									●
1-age migrant	Mar-Jun	4.5%	-0.3%	7							•									⬤
1-age active rearing	Mar-Oct	4.4%	-4.9%	3					•	•								•		⬤
2+-age active rearing	Mar-Oct	0.4%	-2.0%	10																●
2+-age migrant	Mar-Jun	0.4%	0.0%	13							•									●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	1.4%	0.0%	12																●
Prespawning holding	Sep-Apr	1.4%	0.0%	11																●
All Stages Combined		4.5%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

NA = Not applicable

KEY

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-11. A steelhead "consumer reports diagram" for reach BG1 of Badger Gulch Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead		**2014 Rock Creek Steelhead EDT Report - Summer Steelhead**
Restoration Potential:	Current Conditions versus Historic Potential		
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories		

Geographic Area:	Rock Between Luna and Quartz	**Stream:**	Rock Cr
Reach:	Rock Cr Badger Gulch to Unnamed Trib (RM 13.6 - 14.7)	**Reach Length (mi):**	1.10
		Reach Code:	RC7

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	3	**Potential % change in productivity:2/**	26.3%
Overall Restoration Potential Rank:1/	4	**Average Abundance (Neq) Rank:1/**	4	**Potential % change in Neq:2/**	67.9%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	4	**Potential % change in diversity:2/**	12.7%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	2	**% loss in productivity with degradation:2/**	-14.8%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	3	**% loss in Neq with degradation:2/**	-43.6%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	1	**% loss in diversity with degradation:2/**	-47.1%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	Change in attribute impact on survival: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	4.4%	-0.4%	7							Small loss						Small loss			Extreme gain
Egg incubation	Mar-Jun	4.4%	-1.1%	6														Small loss		High gain
Fry colonization	Apr-Jul	6.5%	-4.6%	2					Small loss	Moderate loss	Small loss							Moderate loss		Moderate loss
0-age active rearing	May-Oct	3.7%	-31.0%	1					Moderate loss	Small loss	Small loss				Moderate loss	Small loss		Moderate loss		Moderate loss
0,1-age inactive	Oct-Mar	2.9%	-6.2%	4					Small loss	Small loss	Small loss									Moderate loss
1-age migrant	Mar-Jun	10.8%	0.0%	11																Moderate loss
1-age active rearing	Mar-Oct	2.5%	-6.9%	3						Small loss	Small loss							Small loss		Moderate loss
2+-age active rearing	Mar-Oct	1.0%	-1.6%	8																Moderate loss
2+-age migrant	Mar-Jun	5.3%	0.0%	12																Moderate loss
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	31.9%	0.0%	9																Small loss
Prespawning holding	Sep-Apr	4.4%	-0.1%	10																High loss
All Stages Combined		31.9%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	• (small solid dot)	○ (small open circle)
Moderate	● (medium solid dot)	○ (medium open circle)
High	● (large solid dot)	○ (large open circle)
Extreme	● (very large solid dot)	○ (very large open circle)

Figure C-12. A steelhead "consumer reports diagram" for reach RC7 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Rock Between Luna and Quartz	**Stream:**	Rock Cr
Reach:	Rock Cr Unnamed Trib to Quartz Cr (RM 14.7 - 17.3)	**Reach Length (mi):**	2.70
		Reach Code:	RC8

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	3	**Potential % change in productivity:2/**	26.3%
Overall Restoration Potential Rank:1/	4	**Average Abundance (Neq) Rank:1/**	4	**Potential % change in Neq:2/**	67.9%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	4	**Potential % change in diversity:2/**	12.7%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	2	**oss in productivity with degradation:2/**	-14.8%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	3	**% loss in Neq with degradation:2/**	-43.6%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	1	**% loss in diversity with degradation:2/**	-47.1%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival:** Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	7.9%	-0.3%	7													•			○
Egg incubation	Mar-Jun	7.9%	-0.6%	6														•		
Fry colonization	Apr-Jul	9.8%	-3.5%	2						●								•		●
0-age active rearing	May-Oct	7.7%	-27.3%	1					●	•					•			●		●
0,1-age inactive	Oct-Mar	5.6%	-4.0%	4						•										•
1-age migrant	Mar-Jun	9.6%	0.0%	12																●
1-age active rearing	Mar-Oct	6.1%	-5.2%	3						•								•		●
2+-age active rearing	Mar-Oct	1.4%	-1.4%	8																•
2+-age migrant	Mar-Jun	4.3%	0.0%	13																•
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	27.5%	0.0%	9																•
Prespawning holding	Sep-Apr	7.9%	-0.1%	10																●
All Stages Combined		27.5%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-13. A steelhead "consumer reports diagram" for reach RC8 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Quartz			Stream:	Quartz Cr
Reach:	Quartz Cr mouth to small slide (RM 0 - 2.4)			Reach Length (mi):	2.40
				Reach Code:	QZ1
Restoration Benefit Category:1/	C	Productivity Rank:1/	5	Potential % change in productivity:2/	23.6%
Overall Restoration Potential Rank:1/	5	Average Abundance (Neq) Rank:1/	5	Potential % change in Neq:2/	53.1%
(lowest rank possible - with ties)1/	8	Life History Diversity Rank:1/	6	Potential % change in diversity:2/	5.4%
Preservation Benefit Category:1/	A	Productivity Rank:1/	1	loss in productivity with degradation:2/	-15.4%
Overall Preservation Rank:1/	1	Average Abundance (Neq) Rank:1/	2	% loss in Neq with degradation:2/	-44.2%
(lowest rank possible - with ties)1/	7	Life History Diversity Rank:1/	3	% loss in diversity with degradation:2/	-30.8%

Life stage	Relevant months	% of life history trajectories affected	Productivity change (%)	Life Stage Rank	Change in attribute impact on survival															
					Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	6.3%	-0.3%	8													•			∘
Egg incubation	Mar-Jun	6.3%	-1.6%	5	•													•		●
Fry colonization	Apr-Jul	10.7%	-4.2%	2					•	●	•							•		⬤
0-age active rearing	May-Oct	9.0%	-31.4%	1			•		⬤	•	•				•			●		⬤
0,1-age inactive	Oct-Mar	4.5%	-5.3%	4					•	•	•									●
1-age migrant	Mar-Jun	4.0%	0.0%	12																●
1-age active rearing	Mar-Oct	3.7%	-5.8%	3					•	•	•							•		●
2+-age active rearing	Mar-Oct	0.9%	-2.3%	7																●
2+-age migrant	Mar-Jun	1.5%	0.0%	13																●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	12.6%	0.0%	10																●
Prespawning holding	Sep-Apr	6.3%	-0.1%	9																⬤
All Stages Combined		12.6%																		

1/ Ranking based on effect over entire geographic area.

2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-14. A steelhead "consumer reports diagram" for reach QZ1 of Quartz Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Quartz	**Stream:**	Quartz Cr
Reach:	Quartz Cr small slide to Box Canyon Cr (RM 2.4 - 3.0)	**Reach Length (mi):**	0.55
		Reach Code:	QZ3

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	5	**Potential % change in productivity:2/**	23.6%
Overall Restoration Potential Rank:1/	5	**Average Abundance (Neq) Rank:1/**	5	**Potential % change in Neq:2/**	53.1%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	6	**Potential % change in diversity:2/**	5.4%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	1	**Loss in productivity with degradation:2/**	-15.4%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	2	**% loss in Neq with degradation:2/**	-44.2%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	3	**% loss in diversity with degradation:2/**	-30.8%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival**: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	2.8%	-0.4%	6													•			●
Egg incubation	Mar-Jun	2.8%	-1.9%	3	•													•		⬤
Fry colonization	Apr-Jul	3.9%	-2.7%	2					•	●	•							•		⬤
0-age active rearing	May-Oct	0.7%	-31.9%	1			•		●	•	•				●			●		⬤
0,1-age inactive	Oct-Mar	0.5%	-4.9%	6					•	•										●
1-age migrant	Mar-Jun	1.2%	0.0%	12																●
1-age active rearing	Mar-Oct	0.2%	-11.6%	4			•		•	•	•							●		●
2+-age active rearing	Mar-Oct	0.2%	-3.9%	8														•		●
2+-age migrant	Mar-Jun	0.6%	0.0%	12																●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	6.2%	0.0%	11																●
Prespawning holding	Sep-Apr	2.8%	-0.1%	9																⬤
All Stages Combined		6.2%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	○
Extreme	⬤	◯

Figure C-15. A steelhead "consumer reports diagram" for reach QZ3 of Quartz Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Quartz	**Stream:**	Box Canyon Cr
Reach:	Box Cr mouth to end of distribution (RM 0 - 0.3)	**Reach Length (mi):**	0.30
		Reach Code:	BX1

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	5	**Potential % change in productivity:2/**	23.6%
Overall Restoration Potential Rank:1/	5	**Average Abundance (Neq) Rank:1/**	5	**Potential % change in Neq:2/**	53.1%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	6	**Potential % change in diversity:2/**	5.4%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	1	**% loss in productivity with degradation:2/**	-15.4%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	2	**% loss in Neq with degradation:2/**	-44.2%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	3	**% loss in diversity with degradation:2/**	-30.8%

Life stage	Relevant months	% of life history trajectories affected	Productivity change (%)	Life Stage Rank	Change in attribute impact on survival: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	0.9%	0.0%	10							Small									Moderate
Egg incubation	Mar-Jun	0.9%	-0.6%	6														Small		High
Fry colonization	Apr-Jul	1.4%	-4.0%	2					Small	Moderate	Small							Small		High
0-age active rearing	May-Oct	1.1%	-25.7%	1			Small		Moderate	Small	Small				Small			Moderate		High
0,1-age inactive	Oct-Mar	0.8%	-6.1%	4					Small	Small	Small									Moderate
1-age migrant	Mar-Jun	0.5%	0.0%	10																High
1-age active rearing	Mar-Oct	0.7%	-8.0%	3			Small		Small	Small	Small							Small		High
2+-age active rearing	Mar-Oct	0.1%	-4.0%	7					Small		Small							Small		Moderate
2+-age migrant	Mar-Jun	0.1%	0.0%	10																Moderate
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	0.9%	0.0%	10																Moderate
Prespawning holding	Sep-Apr	0.9%	-0.1%	9																High
All Stages Combined		1.4%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	• (small filled)	○ (small open)
Moderate	● (moderate filled)	○ (moderate open)
High	● (large filled)	○ (large open)
Extreme	● (extra-large filled)	○ (extra-large open)

Figure C-16. A steelhead "consumer reports diagram" for reach BX1 of Box Canyon Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Quartz	**Stream:**	Quartz Cr
Reach:	Quartz Cr Box Canyon Cr to end of distribution (RM 3.0 - 3.8)	**Reach Length (mi):**	0.80
		Reach Code:	QZ4

Restoration Benefit Category:1/	C	**Productivity Rank:1/**	5	**Potential % change in productivity:2/**	23.6%
Overall Restoration Potential Rank:1/	5	**Average Abundance (Neq) Rank:1/**	5	**Potential % change in Neq:2/**	53.1%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	6	**Potential % change in diversity:2/**	5.4%
Preservation Benefit Category:1/	A	**Productivity Rank:1/**	1	**% loss in productivity with degradation:2/**	-15.4%
Overall Preservation Rank:1/	1	**Average Abundance (Neq) Rank:1/**	2	**% loss in Neq with degradation:2/**	-44.2%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	3	**% loss in diversity with degradation:2/**	-30.8%

Life stage	Relevant months	% of life history trajectories affected	Productivity change (%)	Life Stage Rank	Change in attribute impact on survival: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	2.6%	-1.7%	5							Small						Small			Moderate
Egg incubation	Mar-Jun	2.6%	-0.8%	6	Small															High
Fry colonization	Apr-Jul	2.6%	-4.7%	2	Small				Small	Moderate	Moderate									High
0-age active rearing	May-Oct	1.3%	-24.5%	1			Small		High	Small	Moderate				Small					High
0,1-age inactive	Oct-Mar	1.0%	-7.3%	5					Small	Small	Small									Moderate
1-age migrant	Mar-Jun	0.6%	-0.1%	12							Small									High
1-age active rearing	Mar-Oct	0.9%	-6.8%	3			Small		Small	Small	Small									High
2+-age active rearing	Mar-Oct	0.2%	-2.0%	10					Small		Small									Moderate
2+-age migrant	Mar-Jun	0.2%	0.0%	13							Small									Moderate
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	2.6%	0.0%	11																Moderate
Prespawning holding	Sep-Apr	2.6%	-0.2%	9																Moderate
All Stages Combined		2.6%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	● (small filled)	○ (small open)
Moderate	● (medium filled)	○ (medium open)
High	● (large filled)	○ (large open)
Extreme	● (largest filled)	○ (largest open)

Figure C-17. A steelhead "consumer reports diagram" for reach QZ4 of Quartz Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Rock Above Quartz	**Stream:**	Rock Cr
Reach:	Rock Cr Quartz Cr to small falls (RM 17.3 - 18.6)	**Reach Length (mi):**	1.30
		Reach Code:	RC9

Restoration Benefit Category:1/	D	**Productivity Rank:1/**	6	**Potential % change in productivity:2/**	7.9%
Overall Restoration Potential Rank:1/	7	**Average Abundance (Neq) Rank:1/**	6	**Potential % change in Neq:2/**	18.7%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	8	**Potential % change in diversity:2/**	1.8%
Preservation Benefit Category:1/	B	**Productivity Rank:1/**	4	**oss in productivity with degradation:2/**	-6.6%
Overall Preservation Rank:1/	4	**Average Abundance (Neq) Rank:1/**	4	**% loss in Neq with degradation:2/**	-16.9%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	5	**% loss in diversity with degradation:2/**	-21.4%

Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	**Change in attribute impact on survival**															
					Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	4.3%	0.0%	11							Small						Small			High
Egg incubation	Mar-Jun	4.3%	-0.4%	6																High
Fry colonization	Apr-Jul	5.6%	-3.1%	2					Small	Moderate	Small									Moderate
0-age active rearing	May-Oct	4.1%	-20.7%	1					Moderate	Small	Small				Small			Small		Moderate
0,1-age inactive	Oct-Mar	3.5%	-6.3%	3					Small	Small	Small									Small
1-age migrant	Mar-Jun	2.4%	0.0%	11																Moderate
1-age active rearing	Mar-Oct	2.9%	-3.9%	4					Small	Small	Small									Moderate
2+-age active rearing	Mar-Oct	0.7%	-2.1%	7																Small
2+-age migrant	Mar-Jun	1.4%	0.0%	11																Moderate
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	7.0%	0.0%	9																Small
Prespawning holding	Sep-Apr	4.3%	-0.1%	8																Small
All Stages Combined		7.0%																		

1/ Ranking based on effect over entire geographic area.

2/ Value shown is for overall population performance.

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	●	○
Extreme	●	○

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

Figure C-18. A steelhead "consumer reports diagram" for reach RC9 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

Species/Component:	Summer Steelhead
Restoration Potential:	Current Conditions versus Historic Potential
Restoration Emphasis:	Restoration or maintenance/improvement of historic life histories

2014 Rock Creek Steelhead EDT Report - Summer Steelhead

Geographic Area:	Rock Above Quartz	**Stream:**	Rock Cr
Reach:	Rock Cr small waterfall to super slide (RM 18.6 - 20.3)	**Reach Length (mi):**	1.70
		Reach Code:	RC11

Restoration Benefit Category:1/	D	**Productivity Rank:1/**	6	**Potential % change in productivity:2/**	7.9%
Overall Restoration Potential Rank:1/	7	**Average Abundance (Neq) Rank:1/**	6	**Potential % change in Neq:2/**	18.7%
(lowest rank possible - with ties)1/	8	**Life History Diversity Rank:1/**	8	**Potential % change in diversity:2/**	1.8%
Preservation Benefit Category:1/	B	**Productivity Rank:1/**	4	**oss in productivity with degradation:2/**	-6.6%
Overall Preservation Rank:1/	4	**Average Abundance (Neq) Rank:1/**	4	**% loss in Neq with degradation:2/**	-16.9%
(lowest rank possible - with ties)1/	7	**Life History Diversity Rank:1/**	5	**% loss in diversity with degradation:2/**	-21.4%

					Change in attribute impact on survival															
Life stage	**Relevant months**	**% of life history trajectories affected**	**Productivity change (%)**	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Feb-May	2.8%	-0.4%	8							•						•			•
Egg incubation	Mar-Jun	2.8%	-0.4%	7																●
Fry colonization	Apr-Jul	2.8%	-3.0%	2					•	●	•							•		●
0-age active rearing	May-Oct	1.7%	-20.0%	1					●		•				•			•		●
0,1-age inactive	Oct-Mar	1.2%	-6.5%	4					•	•	•									•
1-age migrant	Mar-Jun	0.1%	0.0%	11																●
1-age active rearing	Mar-Oct	0.7%	-6.6%	3					•	•	•							•		●
2+-age active rearing	Mar-Oct	0.7%	-2.3%	6					•											•
2+-age migrant	Mar-Jun	0.7%	0.0%	11																●
2+-age transient rearing																				
Prespawning migrant	Jun-Feb	2.8%	0.0%	10																•
Prespawning holding	Sep-Apr	2.8%	-0.1%	9																●
All Stages Combined		2.8%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	◦
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure C-19. A steelhead "consumer reports diagram" for reach RC11 of Rock Creek. This diagram summarizes the relative impact of habitat factors on the survival of all life stages. The life stages are ranked with 1 representing the most severe impact relative to historical conditions.

The life stages of steelhead most affected by changes in habitat from historic conditions are the age-0 active rearing, fry colonization, and age-0 inactive life stages (Figures C-4–C-8), with age-0 active rearing consistently being the life stage with the greatest loss in productivity in all the reaches. This is true in the tributaries and mainstem. Changes in flow, food, temperature, and key habitat quantity are the principal habitat factors reducing survival in the age-0 active rearing life stage (Figures C-4–C-8). Key habitat quantity is a factor that reduces productivity in nearly every reach and life stage, with the exception of the spawning and egg incubation life stages. In general, the habitat for the spawning and egg incubation life stages is not limiting the steelhead population in Rock Creek.

Summary

The steelhead abundance estimate of the EDT model appears to be reasonable, but lower than what was estimated during juvenile fish abundance sampling and adult steelhead spawning surveys. The EDT model suggests that the reaches with the greatest potential restoration benefit for steelhead abundance are low in the system. This makes sense, because more life history trajectories are affected by conditions low in the system compared with reaches that are in tributaries or further upstream in the system. However, restoration actions in the reaches that are lowest in the system likely also have the greatest potential to be ineffective, or at worst, increase mortality, if the specific restoration sites are not assessed on a finer scale than that used for this modeling effort. The quantity of key habitat affects nearly every life stage to some degree, but the quantity of key habitats for fry colonization and age-0 active rearing life stages are modeled to have the greatest impact on survival and therefore abundance of steelhead. This is due to the reduction in low-flow stream widths and the intermittency of surface flow that occurs as the fry migrate and begin to rear in the remaining pools. Some of the pools are perennial, but many also become dry as the summer progresses. Flow and food are likely limiting the steelhead abundance during this time. We anticipate the results of this modeling will support the priority actions and reaches for restoration and habitat protection.

Ecosystem models, such as EDT, have the ability to combine many environmental variables to identify habitat limitations and prioritize restoration activities. However, due to the large number of variables and the variability and uncertainty associated with each variable (particularly relating to historical conditions), there can be large uncertainties regarding the outputs. The fish habitat in Rock Creek is also spatially diverse during the most limiting time of year, with many small patches of suitable and unsuitable habitat, particularly in the more downstream reaches. Data inputs to the EDT model required spatial averaging of intermittent and perennial habitats to be averaged to each reach, and the model was not designed to be used in intermittent streams. Because of the complexity of the EDT model, estimates of model precision were difficult to assess. McElhany et al. (2010) conducted a sensitivity analysis to quantify the variability in EDT model outputs when a plausible distribution of values were used for each input variable. This sensitivity analysis indicated that the EDT models' productivity and capacity predictions were quite variable. However, the prioritization of reaches for preservation and restoration were more robust to model input variability. They concluded that the EDT model may be more useful as a relative measure of fish performance rather than as an absolute measure.

We feel that, given the uncertainty and variability in input values of some of the variables, the model outputs were reasonable and informative.

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References Cited

Aspect Consulting LLC and Watershed Professionals Network. 2004. Level 1 Watershed Assessment WRIA 31 (Rock-Glade Watershed). Project No. 030009-001-01. Accessed: 2 May 2014 at http://www.klickitatcounty.org/NaturalR/FilesHtml/2008WRIA31/

Barbour, M.T., J.B. Stribling, and J.R. Karr. 1994. Multimetric approach for establishing biocriteria and measuring biological condition, pp. 63-77 in Davis, W.S. and T.P. Simon (eds), Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, CRC Press, Inc., Boca Raton, Florida.

Canale, G. 1999. BORIS – Benthic evaluation of Oregon Rivers. Draft report. Department of Environmental Quality Laboratory - Biomonitoring Section. Portland, Oregon.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59: 66-76.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley & Sons, Ltd., West Sussex, England.

Hawkins, C.P., and 10 coauthors. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18(6): 3-12.

Hyatt, T.L. and R.J. Naiman. 2001. The residence time of large woody debris in the Queets River, Washington, USA. Ecological Applications 11(1) 191-202.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessment of biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Karr, J.R., and E.W. Chu. 1999a. Biological monitoring: essential foundation for ecological risk assessment. Human and Ecological Risk Assessment. 3: 933-1004.

Karr, J.R., and E.W. Chu. 1999b. Restoring life in running waters—better biological monitoring. Island Press, Covelo, CA.

Konrad, C.P. 2000a. The frequency and extent of hydrologic disturbances in streams in the Puget Lowland, Washington. Ph.D Dissertation, University of Washington, Seattle.

Konrad, C.P. 2000b. New metrics to characterize the influence of urban development on stream flow patterns. The Washington Water Resource 11(4):3-6. Available: *http://depts.washington.edu/cuwrm/* (November 2004)

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society 129:262-281.

May, C.W., E.B. Welch, R.R. Horner, J.R. Karr, and B.W. Mar. 1997. Quality indices for urbanization effects in Puget Sound lowland streams. Water Resources Series Technical Report 154, Washington Department of Ecology, Seattle.

Mobrand L. E. 2002. Subbasin Planning with EDT- A primer. Mobrand Biometrics, Inc. Vashon, WA. Available: *http://www.mobrand.com/MBI/pdfs/Subbasin_planning.pdf* (February 2005)

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife. Information Report 97-4, Portland. Available: *http://oregonstate.edu/Dept/ODFW/freshwater/inventory/pdffiles/habmethod.pdf* (December 2004).

Morley, S.A. 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: restoration with a biological focus, Washington, USA. Thesis, University of Washington, Seattle.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Report TFW-F3-92-001, Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife, Olympia.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138; USDA Forest Service, Intermountain Forest and Range Experimental Station, Ogden, UT.

Ptolemy, R.A. 1993. Maximum salmonid densities in fluvial habitats in British Columbia. Pages 223-250 in Proceedings of the 1992 Coho Workshop, Association of Professional Biologists of British Columbia and North Pacific International Chapter of the American Fisheries Society.

Sedell, J.R., and F.H. Everest. 1991. Historic changes in pool habitat for Columbia River Basin salmon under study for TES listing. Draft report, December 1990. Corvallis, Oregon: USDA Forest Service, Pacific Northwest Research Station. 7 p.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006, Washington Department of Natural Resources, Olympia, 224 pp.

Watershed Professional Network (WPN). 2009. WRIA 31 Instream Habitat Assessment, . Grant No. G0900072 July 31, 2009.

3. Genetics

The objectives of the genetic sampling and analysis were: to characterize the *O. mykiss* population structure within the anadromous regions of the subbasin, with a comparison to major stocks and subbasins throughout the Columbia River Basin; and to identify possible stray influences and their distributions throughout the survey area, particularly relative to upstream distance and varied habitat availability (e.g. pool density).

A detailed 2013 genetics report, Report D: "*Genetic evaluation of steelhead trout (Oncorhynchus mykiss) in the Rock Creek watershed of the middle Columbia River Basin*" (Matala, 2014), follows.

Report D: Genetic evaluation of steelhead trout (*Oncorhynchus mykiss*) in the Rock Creek watershed of the middle Columbia River Basin

Drafted by: Andrew P. Matala, Columbia River Inter-Tribal Fish Commission
Date submitted: April 1st, 2014

Objective/Background

These analyses were completed under contract with The Confederated Tribes and Bands of the Yakama Nation, in fulfillment of stated objectives for BPA Project No. 2007-156-00; Contract No. 43057: "Rock Creek Fish and Habitat Assessment for Prioritization of Restoration and Protection Actions". The overall project objective is a characterization of fish habitat within the Rock Creek subbasin to aid future restoration efforts; steelhead productivity may be adversely affected by habitat limitations such as low water flows and riparian degradation. The subbasin supports both anadromous steelhead and resident *Oncorhynchus mykiss*, and is part of the Middle Columbia Distinct Population Segment (DPS) for steelhead, currently listed as "threatened" under the Endangered Species Act (Busby et al. 1996; NMFS 2009 appendix C). There has been limited information available about the status of Rock Creek steelhead and population trends are unknown (WDF and WDW, 1993), although oral Yakama Nation history indicates present day fish populations and habitat conditions have changed dramatically over time (Harvey 2009). Rock Creek summer-run steelhead belong to the inland lineage of *O. mykiss* (*O. m. gairdneri*; Behnke 2002) but are presumably distinct from other mid-Columbia stocks based on geographic isolation of the spawning population (WDF and WDW, 1993).

Anadromous *s*teelhead trout are known to occur in Rock Creek up to at least 0.5 km above the confluence with Quartz Creek (rkm 28.6), and in Squaw Creek up to at least 1.3 km upstream of the confluence with Harrison Creek (rkm 20.3). Adult spawning occurs from February through May. The majority of steelhead redds recorded during redd surveys in 2009 and 2010 were observed in the mainstem of Rock Creek from approximately rkm 1.6 to rkm 22 and in Squaw Creek from rkm 0 to rkm 9. The Rock Creek watershed has no artificial barriers to fish migration (e.g. dams), and there is no directed supplementation activity (i.e. hatchery programs) within the system, but straying of hatchery fish from out-of-basin is likely to occur. Remote instream PIT-tag readers installed by U.S. Geological Survey (USGS) in 2009 have detected the movement of adult steelhead into and out of Rock Creek, and from 2009-2013 there were 34 detections of out-of-basin steelhead, with some remaining in Rock Creek for extended periods.

Juvenile life history information specific to this watershed remains largely undocumented (Lautz 2000). However, biologists from the Yakama Nation in cooperation with USGS gathered baseline information from 2009-2012 to determine the relative abundance and spatial distribution of juvenile anadromous and resident salmonids throughout the watershed (see Report A and spawning survey information in the "Monitoring and Evaluation" chapter). During summer, large portions of streambed typically dry up, leaving the population fragmented within limited pockets of perennial pool habitat. Habitat surveys were conducted in the fall of 2010-2012 to document where fish occur relative to variable and seasonally available habitat, and to measure the length, width, and depth of pools and non-pools in most of the anadromous fish-bearing reaches of the Rock Creek subbasin. Information from PIT-tagged juvenile fish (tagged if >70 mm fork length) indicated that outmigration occurs from March through mid-May; tag detections have provided some indications of seasonal habitat use in the lower river by juvenile *O. mykiss* prior to outmigration.

This report summarizes a genetic evaluation of *O. mykiss* in Rock Creek and Squaw Creek (a tributary of Rock Creek) in the Middle Columbia River Basin (Figure D-1). The objectives are threefold: 1) characterize the *O. mykiss* population structure within the anadromous regions of the subbasin, with a comparison to major stocks and subbasins throughout the Columbia River Basin, 2) examine the population/s for likely extant Rock Creek origin *O. mykiss*, and/or the likelihood of genetic influences from stray steelhead, and 3) define genetic variation relative to the distribution of fish throughout the survey area, particularly relative to upstream distance and varied habitat availability (e.g. pool density).

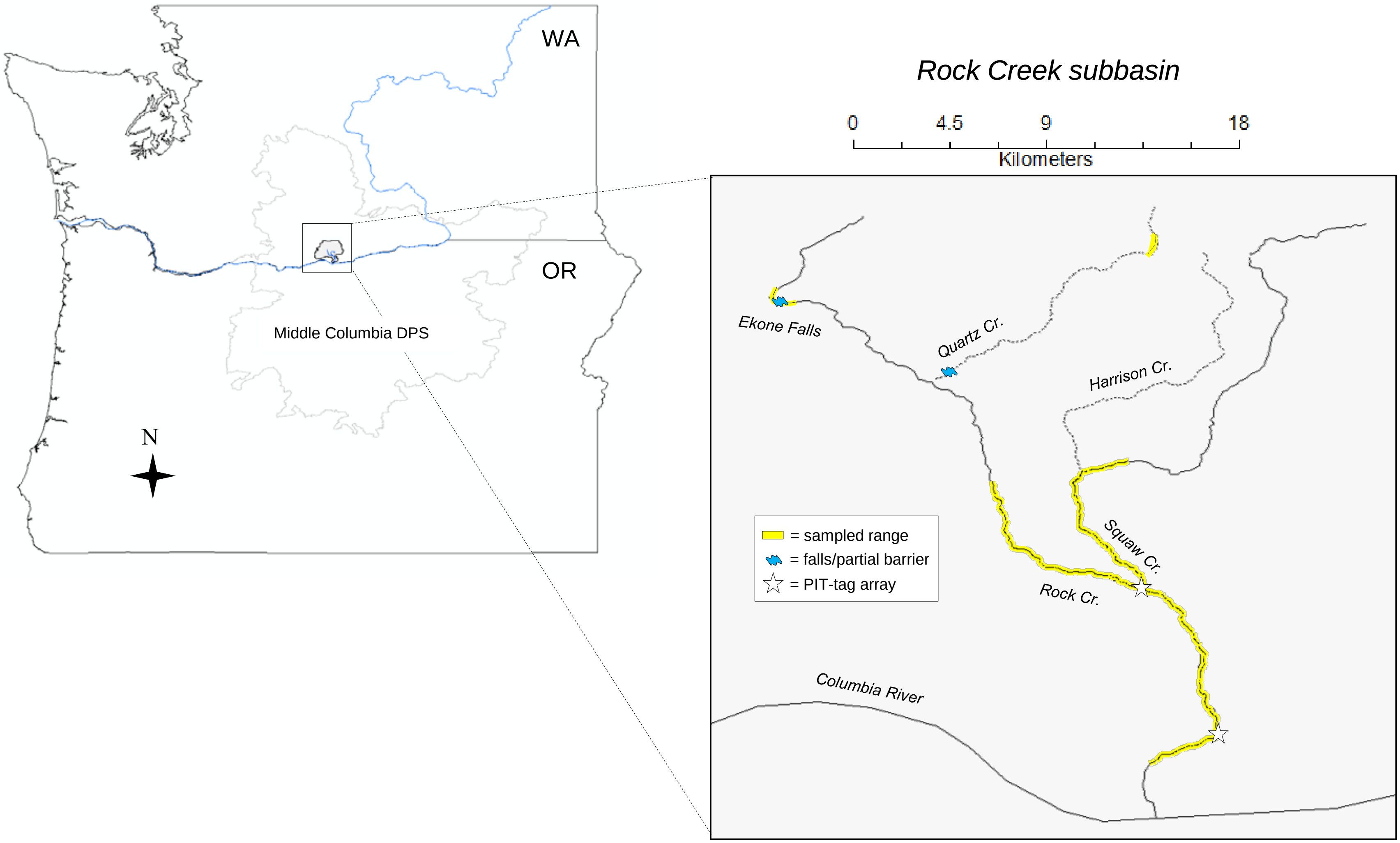


Figure D-1. Map of the Rock Creek Subbasin. The study area outlined indicates the location of Rock Creek in the Middle Columbia River DPS. Primary landmarks within the Rock Creek and Squaw Creek watersheds, including sampled range, are identified on the inset map.

Methods

Sampling design and laboratory protocol

Genomic DNA was extracted from digested tissue samples using a standard Qiagen® DNeasy™ protocol and using a Qiagen® 3000 robotic pipetting system. Samples were genotyped using Taqman chemistry and Fluidigm 96.96 dynamic array chips to generate high throughput genotyping. For additional details on locus/primer specifications, locus optimizations, and detailed laboratory methods, see Hess et al. 2013. In this evaluation, juvenile fish were characterized using 192 (2 panels of 96) single nucleotide polymorphism (SNP) loci developed by CRITFC and Idaho Department of Fish and Game (IDFG). The two 96-panels complement those used in development of a basin-wide genotypic baseline for steelhead, and will aid in identifying distinctions (or similarities) between the Rock Creek/Squaw Creek (RSC) population and populations of inland lineage *O. mykiss* throughout the Columbia River Basin (see Ackerman et al. 2011; Hess et al. 2011 for SNP panel details). Specific populations used to define the baseline for these analyses are described in Hess et al (2013).

Genotypes were compiled for putative juvenile (i.e. immature) *O. mykiss* sampled by electrofishing in the Rock Creek subbasin between the fall sample season of 2008 and spring 2013 (Table D-1). In addition, four post-spawn adult steelhead mortalities collected while conducting spawning surveys were genotyped. The evaluation of collections for these analyses addressed the hypothesis that population structure within RSC may be influenced by out-of-basin straying and migratory limitations. Specifically, in-stream movement may be affected by the distribution of pool habitat for refuge during summer low-water periods and during juvenile rearing. Stream habitat was categorized as 1) non-pool dry, 2) non-pool wet, and 3) pool. Habitat was partitioned using corresponding way points (measured lengths of stream) recorded during surveys conducted by YN and USGS in September of 2011, and September through early October of 2012 (Figure D-2). Habitat was then mapped to the stream network based on way point coordinates of latitude and longitude, and using the GIS program ArcMap version 10.0 (copyright © 1999-2010 ESRI Inc.). Subsequently, temporal sample collections were grouped by river reach, defined in river kilometers (rkm) from the confluence with the Columbia River. Each river reach is loosely bounded by an extended stretch of “non-pool dry” habitat (way points) in conjunction with gaps in sampling coverage along the stream. This resulted in six analysis groups among lower river reaches, ranging in size from n=47 to n=154 (Table D-1; Figure D-2). Sampling was limited between Rock Creek rkm 9-15, and from Rock Creek rkm 9 to Squaw Creek rkm 2, which were subsequently combined for analysis ("rkmS0-2"; Table D-1). Two additional collections were sampled in the upper watershed of Rock Creek (Figure D-1). Samples for the "Ekone Falls" collection (n=56) were taken from a pool directly above the falls (rkm 33) and from 40 m below the falls. These were the farthest upstream in the mainstem Rock Creek. Ekone Falls is a likely seasonal or partial barrier to migration, but is not believed to be a source of complete isolation for adult steelhead. In addition, there is a falls (also a partial barrier) at rkm 29.1 separating Ekone Falls from the next nearest collection at rkm 20-22. The Quartz Creek collection (n=21) was sampled approximately 12 rkm upstream from its confluence with Rock Creek, where there is another possible partial barrier falls.

Table D-1. Analysis collections are defined as temporal samples of *O. mykiss* (Fall 2008-Spring 2013) grouped by river sections (river kilometer; rkm). Proportion of samples by year is variable among analysis collections (e.g. Quartz, Ekone).

collection		analysis collection (rkm)								
year	season	1-9	15-19	20-22	S0-2	S2-8	S8-9	Quartz	Ekone	year total (n)
2008	Fall	33	0	51	70	0	0	0	0	154
2009	Fall	0	20	11	0	19	8	0	0	58
2010	spring	0	12	0	20	11	11	0	0	54
2011	spring	8	37	25	32	5	12	0	0	119
2011	Fall	13	12	10	10	6	16	0	25	92
2012	Spring	8	12	3	15	36	0	0	0	74
2012	Fall	3	0	2	7	12	0	0	0	24
2013	Spring	0	0	0	0	0	0	21	31	52
collection totals (n)		65	93	102	154	89	47	21	56	627

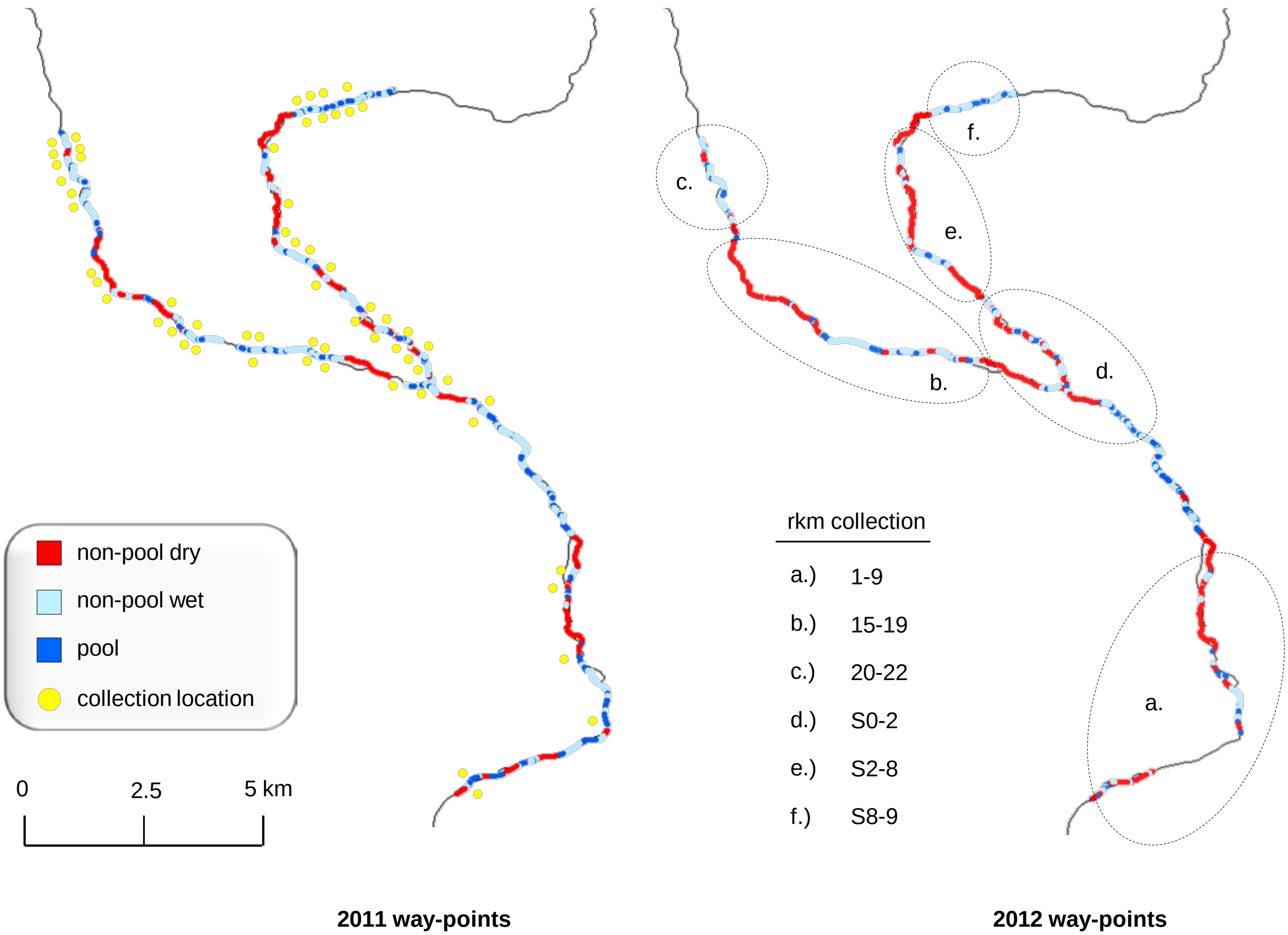


Figure D–2. Map of intermediate stream lengths bounded by habitat way points in the Rock Creek Subbasin. Habitats were surveyed during 2011 (September 2nd- 14th) and 2012 (Sept. 6th – Oct. 4th). All genetic sample locations (including those for 2012-13) are identified on the map showing 2011 way points (left side). Corresponding river reaches bounding collection groups for analyses are identified on the map showing 2012 way points (right side); rkm is river kilometers. "Non-pool dry" is defined as dewatered areas observed during the survey period, and "non-pool wet" are stream areas with wetted gravel but no pools.

Descriptive statistics and structure analyses

Allele frequencies were generated using the analysis program GenAlEx version 6.2 (Peakall and Smouse 2006). The program GENEPOP v. 3.3 (Raymond and Rousset 1995) was used to test for deviations from Hardy-Weinberg equilibrium (HWE) expectations, evaluated across SNP loci and populations to detect non-random mating (e.g., population mixtures). The significance level ($\alpha = 0.05$) was corrected for multiple tests using a modified BY- FDR method (Benjamini and Yekutieli 2001). Pairwise F_{ST} (among-group variation) for all pairs of collections were generated in GENEPOP. A pairwise matrix of Nei's standard genetic distance (Nei 1972) and an un-rooted neighbor-joining (NJ) tree were generated using PHYLIP version 3.68 (Felsenstein 2008) to display the relationship of RSC collections among baseline populations of inland *O. mykiss*. The NJ tree displays the relationship among all populations as their respective proximities in the tree topology (clusters), and the sum of horizontal branch lengths represents the genetic distance between any two populations. The SEQBOOT option was implemented to generate 1000 simulated data sets, and a consensus topology with bootstrap support was generated using the CONSENSE option in PHYLIP. The analysis program GenAlEx version 6.2 (Peakall and Smouse 2006) was used to conduct multivariate principal coordinate analysis (PCA) to graphically display patterns or clusters of genetic similarity among 7 analysis populations. Both the option to convert the F_{ST} distance matrix to a covariance matrix, and the option to standardize results (covariance input/$\sqrt{n-1}$) were implemented.

Genetic stock identification and assignment testing

Genetic stock identification (GSI) analyses were conducted in order to ascertain proportions of exogenous stocks by region of origin among the sampled Rock Creek and Squaw Creek population. Although the Rock/Squaw Creek group may comprise a relatively distinct population within the region (e.g., the Columbia River Basin), these tests help differentiate which populations or regions represented in the SNP baseline for steelhead are most genetically similar or sources of introgression. The program GENECLASS2 (Piry et al. 2004) was used to estimate individual assignment probabilities, implementing the Bayesian method of Rannala and Mountain (1997) in a jackknife, or 'leave-one-out' (LOO) procedure. Each of the six RSC lower reach collections (defined by rkm region) was combined into a single Rock Creek group. Rock Creek, Ekone Falls, and Quartz Creek were then incorporated into a baseline containing 127 inland lineage *O. mykiss* populations. These out-of-basin populations were combined into seven genetically and regionally cohesive groups for improved assignment resolution: 1) Middle Columbia – MC, 2) Upper Columbia - UCOL, 3) Lower Clearwater/Snake/Salmon rivers - LR, 4) Grande Ronde/Imnaha rivers – GRIM, 5) middle and south forks of the Clearwater River – MCSC, 6) middle and south forks of the Salmon River – MSSFS, and 7) Upper Salmon River - UPSal. The assignment process proceeded stepwise by first sequentially removing each individual from the baseline. As each individual was removed, population allele frequencies were recalculated (for its source population), and the removed individual was re-assigned to the most likely group/population of origin in the baseline. After assignment, each individual was returned to the baseline for the evaluation of all subsequent samples. Assignments were ranked as the five highest probability scores corresponding to the most likely population of origin (rank 1 = highest probability, rank 2 = next highest probability, etc.). Note that Rock Creek self-assignments are defined as assignment back to Rock Creek from among all possible baseline groups. Mis-assigned Rock Creek individuals are those assigned with highest probability to any group other than Rock Creek. Following the baseline LOO procedure, stock proportions were estimated by evaluating Rock Creek samples as an "unknown" fishery mixture. A revised baseline was used in which the Ekone Falls and Quartz Creek collections were the sole representatives of the Rock Creek Subbasin. Using the same Bayesian method in GENECLASS2, individuals in the "unknown" group were then assigned to the most likely baseline population of origin (1^{st} ranked probability score) based on similarity between the individual's multilocus genotype and baseline population allele frequencies.

Genetic stock identification was also evaluated for four adult steelhead encountered in Rock Creek from 2010-2012, and for tagged fish detected at PIT-tag arrays located at ~rkm 5 and ~rkm 13 at the Rock Creek and Squaw Creek confluence. Eleven of the 34 adult fish that were detected in Rock Creek were originally tagged at Bonneville Dam, and therefore the natal spawning grounds or tributary of origin of each was unknown.

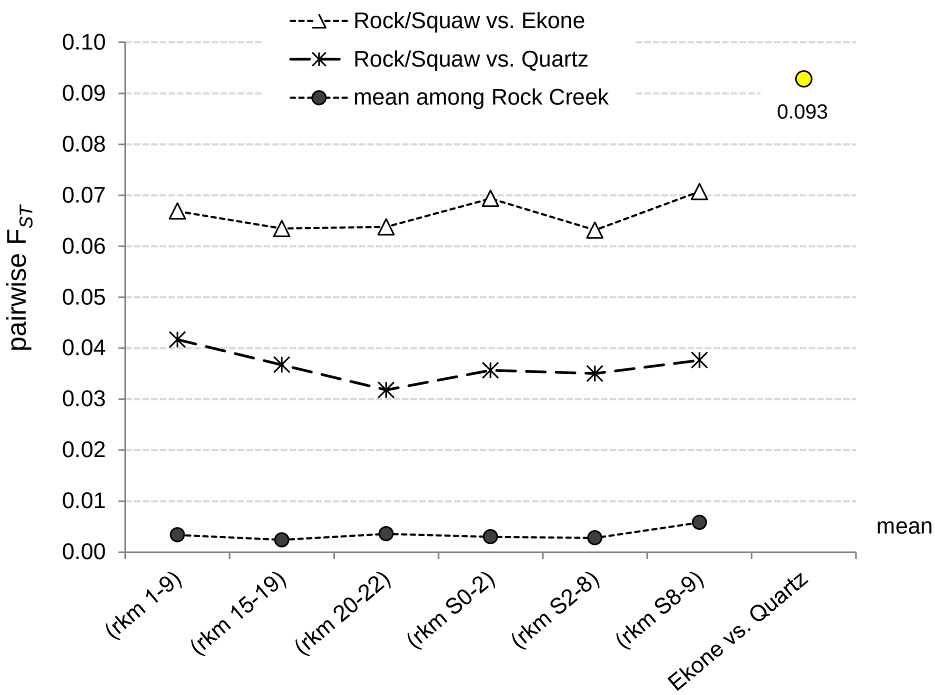
Estimating relatedness

The program ML-Relate (Kalinowski et al. 2006) was used to estimate relatedness between all pairs of individuals within each of the eight analysis groups. Relatedness was calculated from maximum likelihood estimates designed for codominant loci, using simulations to determine relationships consistent with genotypic data for individual pairs. If the coefficients k_0, k_1 and k_2 represent the probabilities that two individuals share zero, one, or two alleles (respectively) at a locus, then two individuals that are full-siblings will have $k_0 = 0.25$, $k_1 = 0.5$ and $k_2 = 0.25$.

Results

Results of Hardy-Weinberg equilibrium tests indicated no inherent population-specific deviations from expectations, although kinship or out-of-basin genetic influences may have contributed to some issues of genotypic disequilibrium. Pairwise F_{ST} revealed significant differentiation between RSC collections and Ekone Falls, and between RSC collections and Quartz Creek. The pairwise mean across all comparisons between the six lower-reach groups (i.e. spatially based variation) was $F_{ST} = 0.004$, the mean between RSC groups and Ekone Falls was $F_{ST} = 0.066$, and the mean between RSC and Quartz Creek was $F_{ST} = 0.036$. Interestingly, the highest pairwise value indicating greatest differentiation was observed between Ekone Falls and Quartz Creek ($F_{ST} = 0.093$; Figure D-3). Numbers of samples collected per reach, per year were highly variable. Therefore, among-group variation was also evaluated based on sample year to account for potential biases arising from inter-annual variation. However, no significant temporal variation was observed between RSC collections, and results were highly concordant with results based on spatial differentiation among groups. The pairwise mean across all comparisons between years was $F_{ST} = 0.002$ (slightly less than spatial variation), the mean between RSC groups and Ekone Falls was $F_{ST} = 0.066$, and the mean between RSC and Quartz Creek was $F_{ST} = 0.035$ (Figure D-3b). The genetic distance topology in a neighbor joining tree and clustering of sample groups in PCA plots provide corroborating evidence that the uppermost collection from the Ekone Falls area of Rock Creek is highly distinct from all remaining temporal collections grouped by river reach (rkm; figures D-4 & D-5). Ekone Falls and Quartz Creek clustered most closely with baseline collections from the Middle Columbia River, while the remaining six Rock Creek groups clustered most closely with Snake River groups. Lastly, there is a noticeable branch distinction between the two upper Squaw Creek analysis groups (rkmS2-8 and rkmS8-9) and all remaining RSC groups (Figure D-4).

a.)



b.)

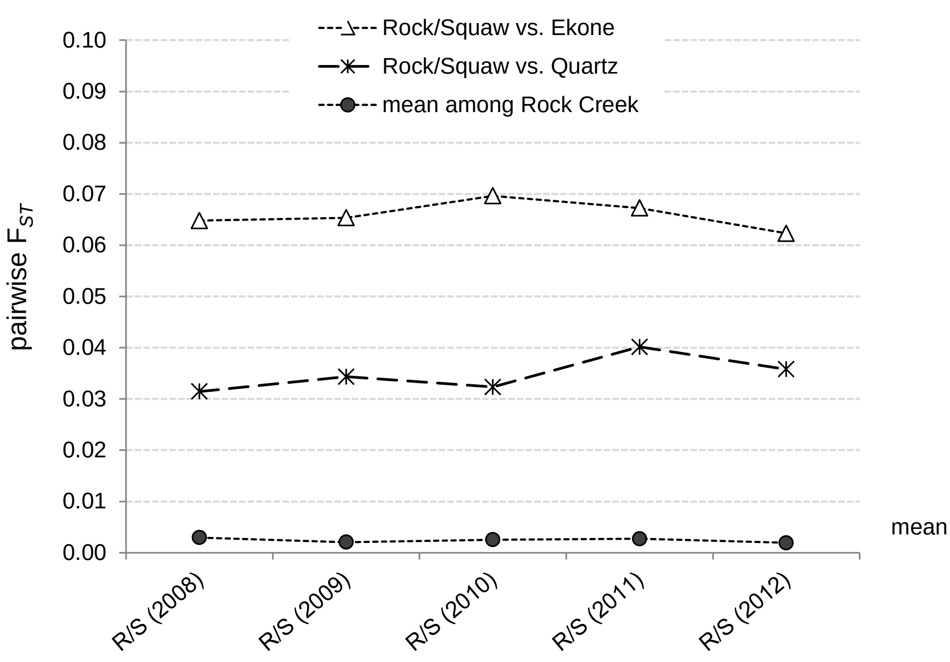


Figure D–3. Relative amounts of genetic variation among groups defined by river reach (a) and defined by sample year (b). In comparisons among Rock Creek collections only, results for each collection are the mean pairwise FST values (Y-axis). Comparisons between Rock Creek and either Quartz Creek or Ekone Falls are actual pairwise values.

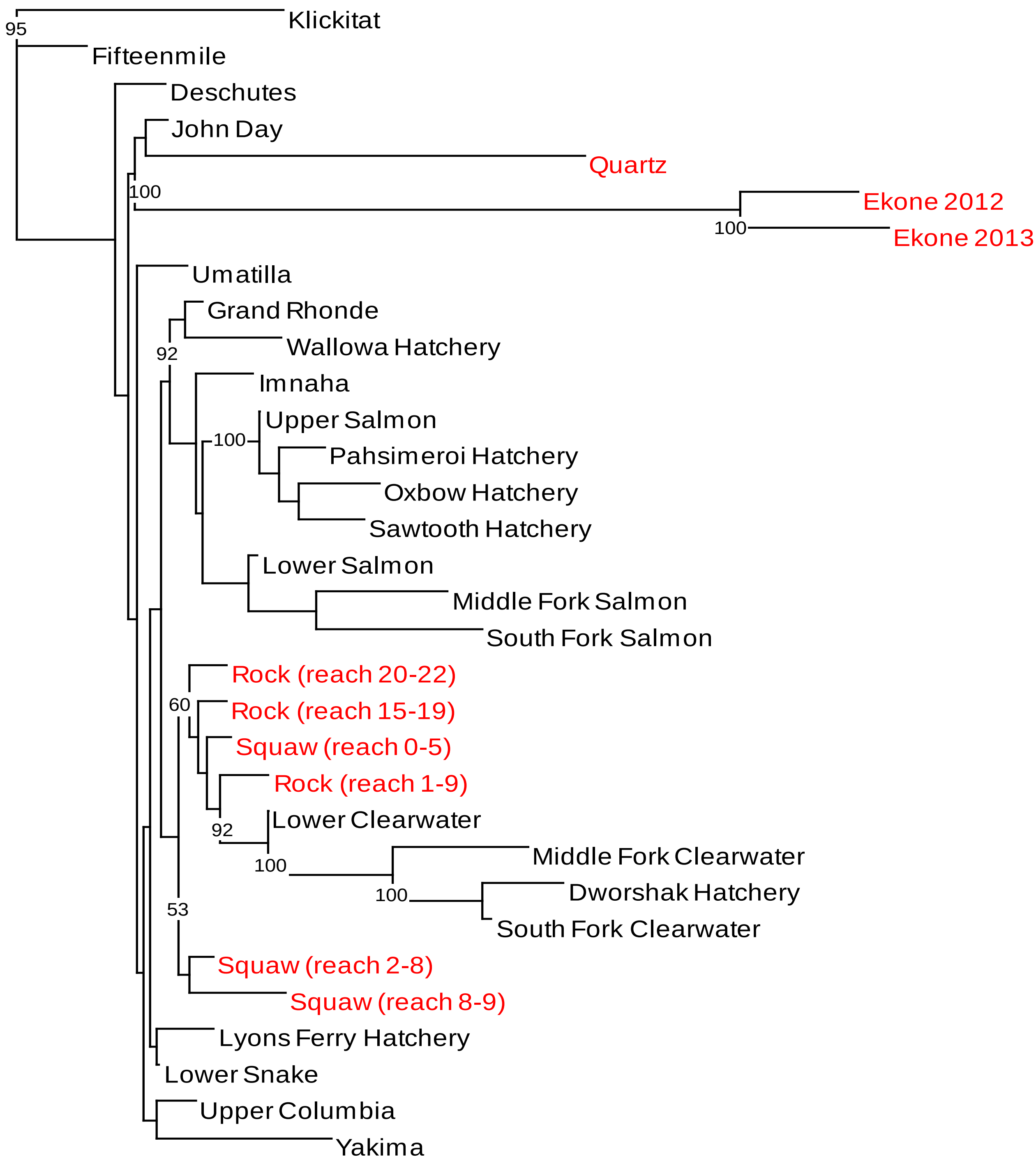


Figure D-4. Neighbor joining tree. The topology shows Nei's genetic distance between collections from the Rock Creek Subbasin (by river reach) and primary out-of-basin stocks of inland lineage *O. mykiss* represented from throughout the Columbia River Basin.

a.

b.

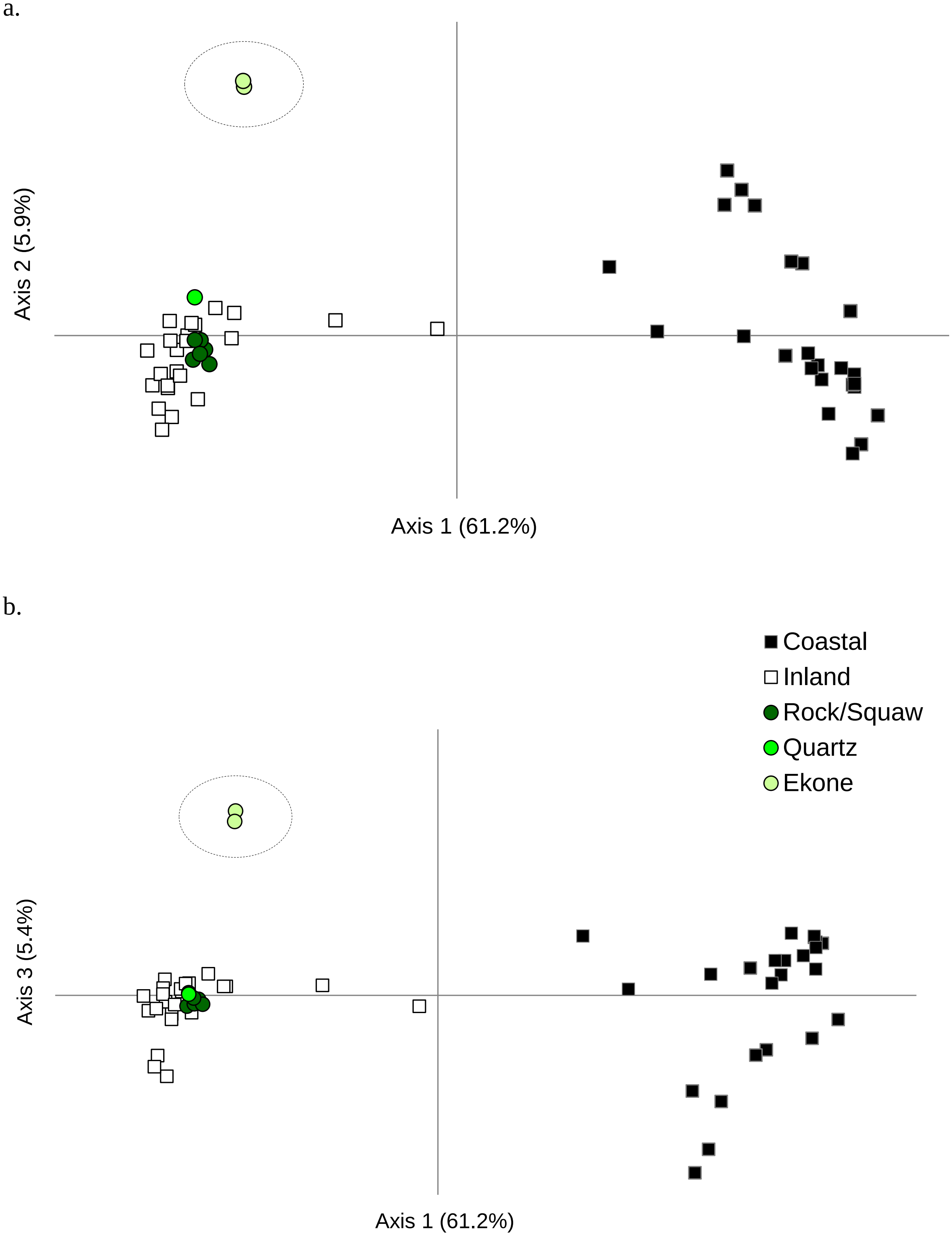
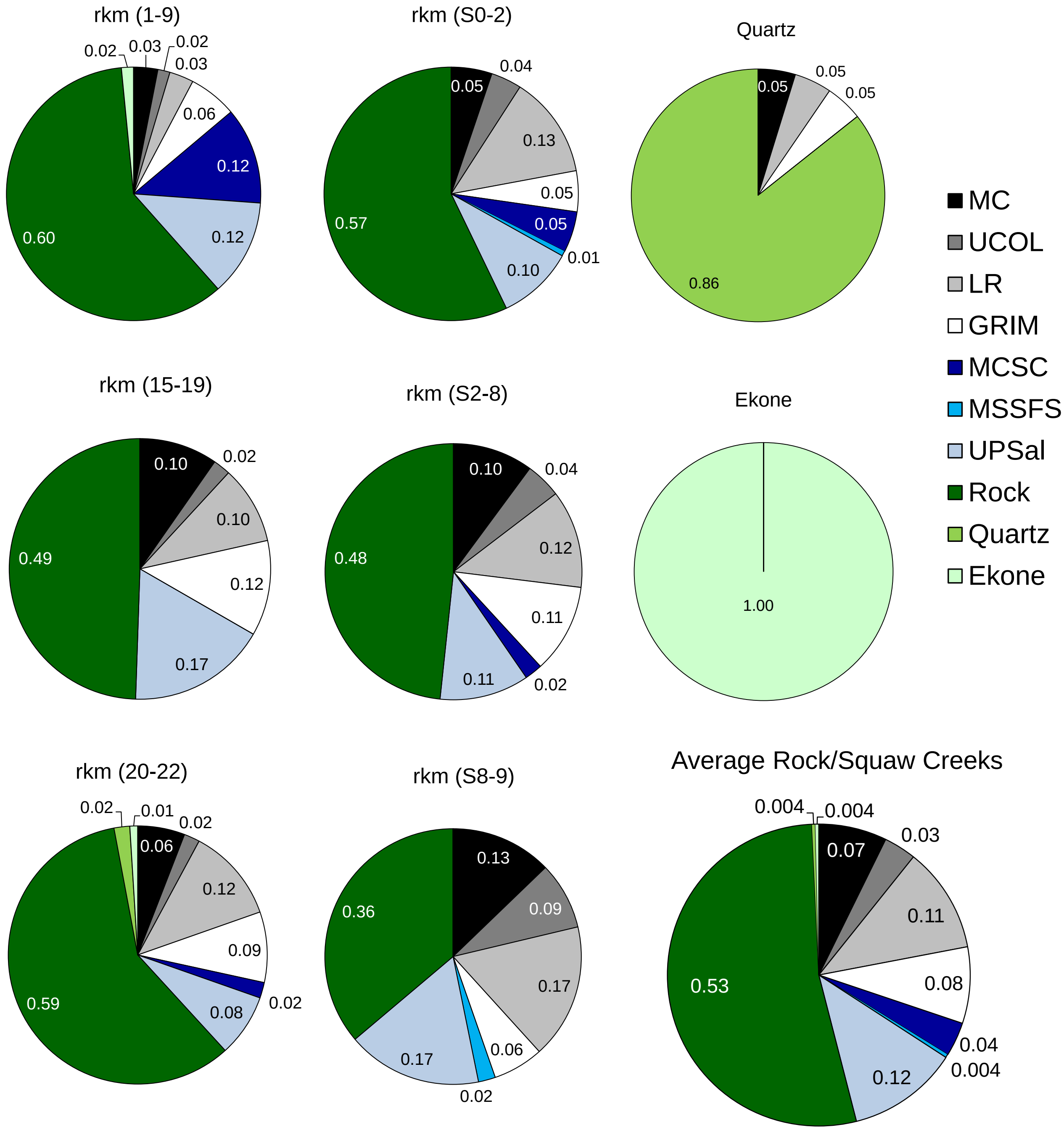


Figure D-5. Principal coordinates analysis plot. Two perspectives (a and b) show the same ordination of data rotated on the axes. Ellipses highlight distinction of the Ekone Falls collections from both baseline coastal lineage collections (black squares) and baseline inland lineage collections (white squares).

Results of individual assignments using the LOO approach and the full inland *O. mykiss* baseline indicated variable accuracy in self-assignment rate among the six RSC analysis groups in the lower reaches. Although results included the five highest-ranked assignments (by descending probabilities), only first-ranked assignments were evaluated. Self-assignment proportions ranged from 36% in the rkmS8-9 group to 60% for rkm 1-9 (mean 53%; Figure D-6a). Those same two lower reach collections also had the lowest and highest average assignment probabilities (P), with P=58% and P=75% respectively. In the rkm 20-22 collection there were two individuals that “mis-assigned” to Quartz Creek and a single “mis-assignment” to Ekone Falls. There was also a single individual in the rkm 1-9 collection that “mis-assigned” to Ekone Falls. No Ekone Falls or Quartz Creek assignments were observed among the remaining RSC collections. Among all RSC individuals, there were no observed assignments to Ekone Falls or Quartz Creek among 2nd ranked assignments (i.e. next most likely). Lastly, large and variable proportions of out-of-basin (stray) influences were present in all six RSC collections based on assignment results. All 56 individuals from Ekone Falls assigned specifically to Ekone Falls with 100% assignment probability, while 18 of 21 Quartz Creek individuals self-assigned with an average assignment probability of 93%.

In the second part of the assignment analysis, all RSC individuals were treated as fish of “unknown” origin and evaluated against the reference baseline in which only Ekone Falls and Quartz Creek collections represented the Rock Creek Subbasin. Nearly all individuals across the six RSC groups failed to assign to Ekone Falls (Figure D-6b). The exceptions were the four fish identified in the previous analysis as mis-assigned individuals. Assignment to the Middle Columbia (MC) and lower rivers of the Snake River basin (LR) regions occurred most frequently.

a.)


rkm (1-9)
0.02
0.03
0.02
0.03
0.06
0.12
0.12
0.60
rkm (S0-2)
0.05
0.04
0.13
0.05
0.05
0.01
0.10
0.57
Quartz
0.05
0.05
0.05
0.86
MC
UCOL
LR
GRIM
MCSC
MSSFS
UPSal
Rock
Quartz
Ekone
rkm (15-19)
0.10
0.02
0.10
0.12
0.17
0.49
rkm (S2-8)
0.10
0.04
0.12
0.11
0.02
0.11
0.48
Ekone
1.00
rkm (20-22)
0.02
0.01
0.02
0.06
0.12
0.09
0.02
0.08
0.59
rkm (S8-9)
0.13
0.09
0.17
0.06
0.02
0.17
0.36
Average Rock/Squaw Creeks
0.004
0.004
0.07
0.03
0.11
0.08
0.04
0.004
0.12
0.53

b.)

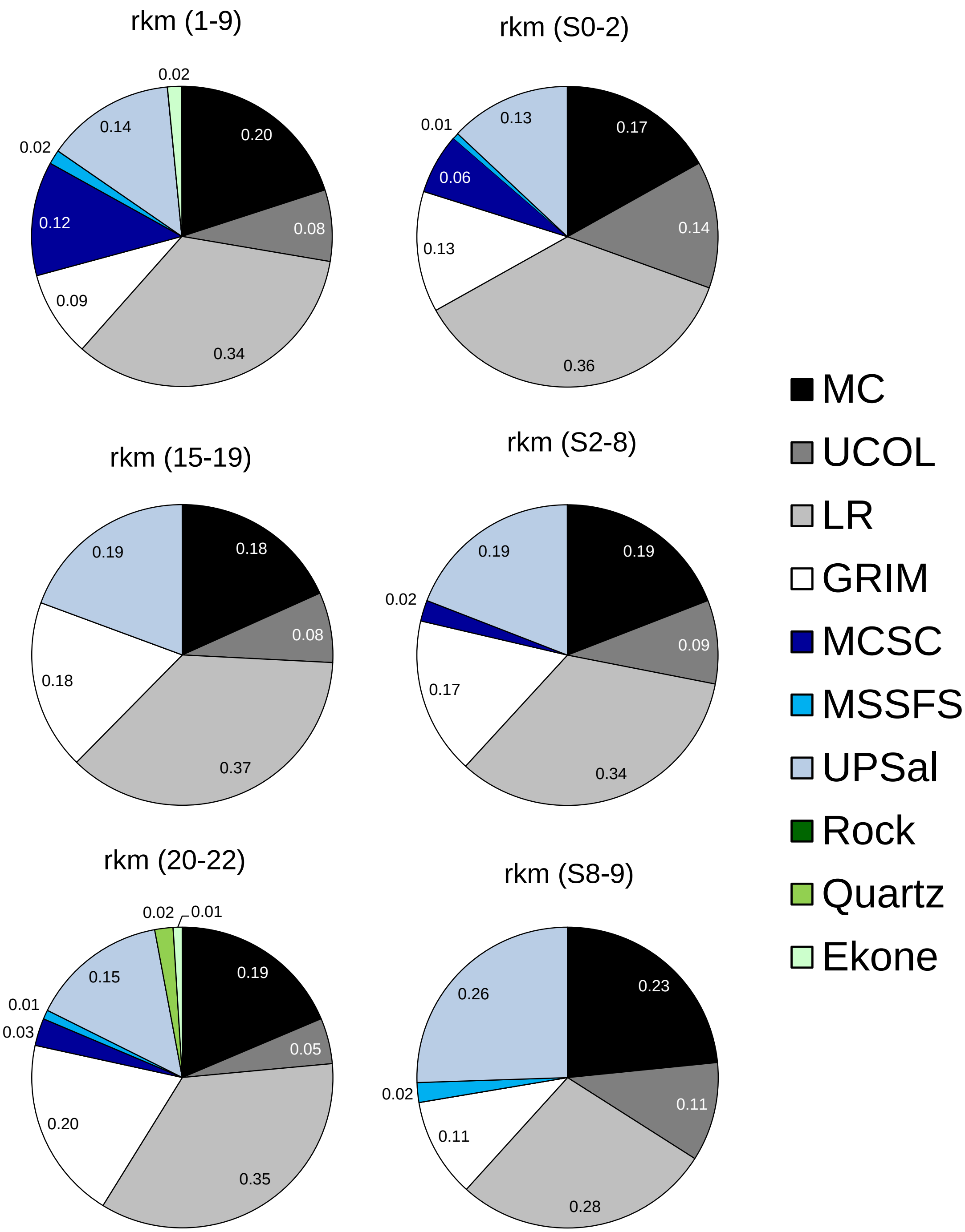


Figure D-6. Pie charts identify proportional assignments using the individual jackknife assignment method (leave-one-out) implemented in the program GENECLASS2 (a). The entire *O. mykiss* reference baseline was employed to evaluate assignment accuracy. The basline groups included Ekone Fall, Quartz Creek, and a group defined by all lower river reaches of Rock/Squaw creeks in which individuals were not distinguished by reach. Results reflect the highest ranked assignment, irrespective of probability level. Self-assignment (dark green) to Rock Creek is the proportion of Rock Creek fish that assigned back to Rock Creek. In a second analysis, individuals from all Rock Creek collections (excluding Ekone Falls and Quartz Creek) were treated

as "unknown" origin. Using the unknown mixture assignment method of GENECLASS2, each fish was assigned to likely origin (highest ranked probability) from among all baseline populations, where the basline included Ekone Falls and Quartz Creek. Pie charts (b) indicate assignment proportions by Rock Creek river reach from among all "unknowns".

In a clustering analysis, all collections from the Rock Creek Subbasin grouped with populations of the inland lineage relative to the primary principle coordinate (axis 1) that explained the largest proportion of total variation in the data (Figure D-5). Among inland lineage populations Ekone Falls appears as the most highly differentiated from this perspective. Despite differences within the inland group, each population appears highly distinct from the coastal lineage baseline collections.

Kinship analyses that reveal relatedness among individuals within groups exhibited similar proportions of full-siblings (<1%), half-siblings (~4 to5%) and unrelated pairs of individuals (~95%) across RSC groups (Figure D-7). Ekone Falls and Quartz Creek were similarly dominated by unrelated pairs of individuals (90% and 89% respectively). However, both of the latter groups exhibited a higher proportion of full-siblings (2% and 4% respectively) and a small number of inferred parent/offspring relationships. The proportion of fish within each analysis group that were deemed mature (not juveniles: fork length >= 150mm) varied from 8.8% in the rkm20-22 group to 47.6% in the Quartz Creek group (Table D-2). Mean and median length among groups favored both Ekone Falls and Quartz Creek, but larger fish were found within 4 of 6 lower reach RSC collections.

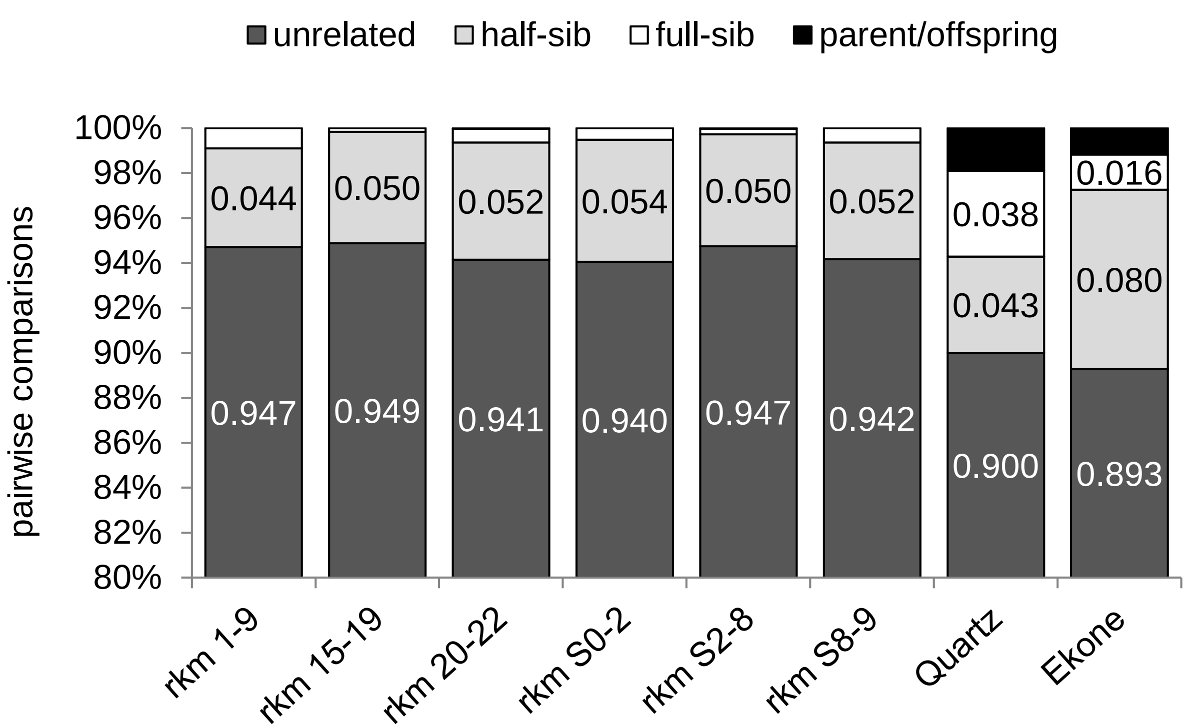


Figure D-7. Histogram of proportional relatedness within each of the seven collections defined by river kilometer (rkm) or upstream location. Categories of relatedness are full sibling pairs (same parent pair), half-sibling pairs (sharing either mother or father), pairs of individuals with an inferred parent/offspring relationship, and unrelated pairs.

Table D-2. Fork-length distribution of *O. mykiss* by collection site: six lower river reaches, Ekone Falls and Quartz Creek. A fork length (FL) of 150-mm is a presumed lower limit on potential size at sexual maturity. Bold values indicate largest mean and median fork lengths. Shaded values indicate lower reach collections with sample individuals that were larger than upstream collections from Ekone Falls and Quartz Creek.

	analysis collection (rkm)								
FL >=150mm	1-9	15-19	20-22	S0-2	S2-8	S8-9	Quartz	Ekone	overall
#	7	21	9	21	22	7	10	23	79
% total (n)	10.8	22.6	8.8	13.6	24.7	14.9	47.6	41.1	16.6
mean	108.2	122.2	103.2	103.6	105.9	103.1	**113.9**	**114.8**	105.6
min	40	37	49	33	32	38	105	32	---
max	260	268	180	239	265	220	210	212	---
median	92	124	115	76	112	88	**144**	**137**	---

Eleven adult steelhead detected at PIT-tag arrays in Rock Creek between 2009-2012 were originally genetically sampled and PIT-tagged in the adult fish facility while passing Bonneville Dam, located downstream of the Rock Creek and Columbia River confluence (results gathered using the PTAGIS database maintained by Pacific States Marine Fisheries Commission). These fish were therefore considered to be of unknown origin with regard to natal stream prior to genetic analyses. Using genetic stock identification, two PIT-tagged fish assigned with highest probability to the Rock Creek subbasin, but most were identified as out-of-basin strays (Table D-3). Using GSI, four adult fish sampled during carcass surveys in Rock Creek between 2010 and 2012 were identified as Middle Columbia region fish, assigning with highest probability specifically to the Deschutes River or Fifteenmile Creek.

Table D-3. Genetic stock identification (GSI) results for adult steelhead PIT-tagged at Bonneville Dam and detected in Rock Creek. "Adult sample" indicates post spawn adults collected in Rock Creek. Origin is wild (W), hatchery (H), or unknown (U). Tag date is the date of initial tagging (or carcass survey date for "Adult sample"). RCL is the lower PIT-tag array at ~rkm 5, and RCS is the upstream array near rkm 13 at the confluence of Rock and Squaw creeks. Entries for "upstream" are the farthest upstream detection from Bonneville Dam. Assignments are given to region and population within region with associated probabilities. Bolded assignments represent discrepancies between region and population. Two fish (red text) were repeat spawners detected in Rock Creek.

			RCL		RCS			assignment		assignment	
PIT tag#	Origin	Tag Date	1st Obs	last	1st Obs	last	upstream	region	Prob.	population	Prob.
3D9.1C2D0791A3	W	09/04/09	02/07/10	---	---	---	MDA	MC	0.392	***MF Clearwater***	***0.264***
3D9.1C2D09C8BD	H	07/16/09	03/27/10	04/10/10	03/29/10	04/09/10	IHD	GR	0.722	Crooked River	0.511
3D9.1C2D0A2039	W	08/11/09	02/06/10	03/22/11	02/08/10	03/13/11	MDA	MC	0.936	Rock Creek	0.536
3D9.1C2D0C2807	W	07/14/09	01/18/10	02/27/10	---	---	RC	MC	0.971	Rock Creek	0.924
3D9.1C2D2CA56A	W	08/19/09	01/22/10	02/22/11	---	---	RC	UPS	0.804	Sawtooth Hat.	0.708
3D9.1C2D416CC3	W	07/28/10	---	---	03/04/11	---	MDA	UPS	0.929	NF Salmon	0.401
3D9.1C2D70377F	W	09/21/11	01/31/12	04/12/12	02/11/12	02/12/12	RC	LC	0.492	Little Bear	0.488
3D9.1C2DAC47BF	W	07/19/11	12/30/11	---	01/01/12	01/31/12	MDA	UC	0.955	Methow	0.636
3D9.1C2DB14980	W	07/22/11	02/11/12	02/27/12	---	---	RC	MC	0.351	***Sawtooth Hat.***	***0.221***
3D9.1C2DE890DB	W	08/24/12	03/10/13	03/13/13	03/14/13	---	MDA	UPS	0.580	***UC***	***0.351***
3D9.1C2E038361	W	07/19/13	02/15/14	---	02/25/14	---	RC	MC	0.814	***UPS***	***0.178***
Adult sample	U	04/12/11	---	---	---	---	rkmS0-2	MC	0.942	Deschutes	0.942
Adult sample	U	04/13/11	---	---	---	---	rkmS0-2	MC	0.982	Fifteenmile	0.982
Adult sample	U	04/25/12	---	---	---	---	rkm20-22	MC	1.000	Deschutes	0.782
Adult sample	U	05/06/13	---	---	---	---	rkm20-22	MC	1.000	Fifteenmile	0.999

RCS= Rock/Squaw Creek; RCL=Rock Creek at Longhouse; MDA=McNary Dam Fishway; RC=Rock Creek; IHD=Ice Harbor Dam
MC=Middle Columbia; UC=Upper Columbia; GR=Grande Ronde; UPS=Upper Salmon; LC=Lower Clearwater

Discussion

With the likely exclusion of the sample area adjacent to Ekone Falls (rkm 33) and Quartz Creek, all sample collections that were evaluated from 2008-2012 represent fish residing within the putative range of anadromy in the Rock Creek Subbasin. The results presented here indicate genetic similarity between Rock Creek analysis groups in the lower Rock Creek reaches and several exogenous regions of the Columbia River Basin. There is sufficient evidence to conclude that out-of-basin genetic influences from stray fish are prevalent and spatially distributed throughout the surveyed range below Rock Creek rkm 22 (results supported by PIT-tag data in the companion USGS report). These influences likely extend up to rkm 29, but no fish sampling was conducted between rkm 22 and the partial barrier falls at rkm 29. Many individual fish from the six downstream analysis groups also assigned with high accuracy to the Rock Creek Subbasin, which may suggest that the subbasin still supports a distinct local component (Appendix D). Alternatively, these results suggest that a high degree of similarity between upstream Columbia River populations and Rock Creek fish has effectively diminished our ability to genetically differentiate between those sources with confidence, leading to low assignment probabilities and high mis-assignment rates.

No significant population distinction is evident among six lower river reaches, as each appears highly (and generally uniformly) introgressed with out-of-basin sources. Proportions of stray influences partitioned by exogenous region of origin appear to be far more variable than do the overall proportions of influence by stray fish from one RSC river reach to the next. In fact, some of the sample areas farthest upstream (e.g., rkmS8-9) indicate some of the largest proportions of out-of-basin influence. Considering the general panmictic genetic characterization of the RSC population throughout the stream corridor, it appears that the seasonal distribution of stream habitat types (particularly seasonal stretches of dry river bed) has no discernible bearing on, or limitations to how steelhead utilize and move throughout the estimated range of anadromy. Note the high level of consistency between habitat survey years in which the distributions of pool habitat and dry river stretches overlap (Figure D-2). This suggests there may be minor inter-annual variation in seasonal stream habitat hydration patterns. Further, habitat patterns are likely to affect overwintering juveniles to a greater degree than adults, which are spawning between

February and May. Note, for example, that habitat designations in fall presumably do not apply to river conditions during spawning months.

The unique genetic attributes of the Ekone Falls and Quartz Creek collections are in stark contrast to the previous conclusion regarding movement between sampled reaches in the lower river. There is a significant lack of out-of-basin influence (i.e. anadromous fish) above the confluence with Quartz Creek (rkm 28.6). Interestingly, these two collections are highly differentiated from each other, at a level that exceeds differences between either of these and six RSC lower river collections. It is likely that these two collections represent remnant Rock Creek resident *O. mykiss* populations that have undergone significant genetic drift, and that have been buffered from introgression. Despite the apparent inconsequential effect of in-stream habitat distributions (i.e. pools vs. dry river bed) on putative steelhead migration, the falls that occur intermediate to Quartz Creek and RSC, and intermediate to Ekone Falls and RSC are presumably only partial seasonal barriers to steelhead migration (based on the height of the falls). The isolation of upstream populations may have arisen as a result of combined obstacles including partial barrier falls, and seasonally dry stretches of river bed. Moreover, these attributes likely affect the distributions of juvenile *O. mykiss* more so than spawning steelhead. Fish in upstream populations have the potential to "fall out" from those locations and move downstream, even if barriers preclude the possibility of upstream movement. Yet, with the exception of four fish collected in two lower reaches (previously described), the occurrence of fish resembling (genetically) either Ekone Falls or Quartz Creek populations among RSC collections are essentially absent (Figure D-6b).

Similar conclusions have also been reached in other river systems with natural migratory barriers (e.g., falls) or habitat variation related to upstream distance (Currens et al. 2007; Schroeder 2007; Narum et al. 2008). The distinctions of the Ekone Falls and Quartz Creek collections are not representative of influences from stocked coastal lineage *O. mykiss*, based on these analyses. Fish from upstream locations were significantly larger in fork length, indicating higher proportions of sexually mature individuals, and potentially a resident life history. There was no evidence of bias resulting from relatedness or groups of highly related individuals within any collection evaluated. However, the populations farther up in the basin may be relatively smaller than the population occupying the lower surveyed reaches. Some juvenile fish in lower reaches may be two-year-old vs. one-year-old smolts, but no age data were available for the samples in this evaluation. It is important to reiterate that most individuals sampled below rkm 23 (no samples were collected between rkm 23 and rkm 33) identified more accurately with anadromous baseline populations (despite their exogenous origins) rather than the putative resident signature represented specifically by the Ekone Falls and Quartz Creek collections from the same watershed. If and when resources allow, characterization of the RSC population is likely to benefit greatly from continued genetic monitoring and evaluations. Follow-up analyses could include archival samples (if available), additional samples from the Ekone Falls and other headwater areas, and adult steelhead moving through the system; PIT-tag data to date has proven highly informative and supports the findings of this genetic analysis. Archival samples will allow a glimpse through time that may indicate significant temporal variation, where historically the population may have been well differentiated from, and/or less impacted by exogenous stocks. Other current genetic tools (i.e. parentage-based tagging database; Steele et al. 2012) may allow highly confident identification of individuals that are the progeny of Snake River hatcheries.

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References

Ackerman, M., and M. Campbell. 2011. Chinook and steelhead genotyping for genetic stock identification at lower granite dam. ANNUAL PROGRESS REPORT July 1, 2010 — June 30, 2011 Submitted to Bonneville Power Administration. Contract #48347; Project # 2010-026-00

Behnke, R. J. 2002. Trout and Salmon of North America. Free Press, Simon and Shuster, Inc. N.Y., N.Y. pages 75-86.

Benjamini Y., and D. Yekutieli. 2001. The control of false discovery rate under dependency. Ann. Stat. 29:1165-1188.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. Technical memorandum NMFW-NWFSC-27. National Oceanic and Atmospheric Administration, Seattle, Washington. (Also available from *http://www.nwr.noaa.gov/1salmon/salmesa/pubs.htm#* Status Reports).

Currens, K. P., C. B. Schreck and H. W. Li. 2007. Pages 12-13 in R. K. Schroeder and J.D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis

Felsenstein, J. 1992. PHYLIP (Phylogeny Inference Package) Version 3.5C. Department of Genetics. SK-50, University of Washington, Seattle, 98195, USA.

Harvey, E. 2009. Rock Creek Fish and Habitat Assessment for Prioritization of Restoration and Protection Actions. 2008 Annual Report. Submitted to: U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number 2007-156-00; Contract Number 43057.

Hess, J. E., N. Campbell, A. P. Matala and S. R. Narum. 2011. Genetic assessment of Columbia River Stocks: 2010 annual report. Submitted to Bonneville Power Administration. Contract #41224; Project # 2008-907-00 https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P120015

Hess, J. E., N. Campbell, A. P. Matala and S. R. Narum. 2013. Genetic assessment of Columbia River Stocks: 2012 annual report. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number: 2008-907-00Contract Number: 41224.

Kalinowski ST, AP Wagner, ML Taper (2006). ML-Relate: a computer program for maximum likelihood estimation of relatedness and relationship. *Molecular Ecology Notes* 6:576-579.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors. Washington State Conservation Commission Report.

Narum, S. R., J. Zendt, D. Graves, and B. Sharp. 2008. Influence of landscape on resident and anadromous life history types of *Oncorhynchus mykiss*. Can. J. Fish. Aquat. Sci. 65:1013-1023.

National Marine Fisheries Service (NMFS). 2009. Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan. NMFS Northwest Region, Portland, Oregon.

Nei, M. 1972. Genetic distance between populations. The American Naturalist 106:283-292.Peakall, R., P.E. Smouse. 2006. GENALEX 6: genetic analysis in Excel. Population genetic software for teaching and research. Molecular Ecology Notes 6, 288-295.

Piry S, Alapetite A, Cornuet, J.-M., Paetkau D, Baudouin, L., Estoup, A. (2004) GeneClass2: ASoftware for Genetic Assignment and First-Generation Migrant Detection. Journal of Heredity 95:536-539.

Rannala, B. and J. L. Mountain (1997) Detecting immigration by using multilocus genotypes. Proc. Natl. Acad. Sci. USA 94: 9197-9221.

Raymond, M. and F. Rousset. 1995. Genepop: population genetics software for exact tests and ecumenicism. Journal of Heredity 83: 248-249.

Schroeder, R. K. 2007. Pages 65–75 in R. K. Schroeder and J.D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis

Steele, C., M. Ackerman, J. McCane, M. Campbell, M. Hess and S. Narum. 2012. Parentage based tagging of Snake River hatchery steelhead and Chinook salmon. 2011 Annual Report. Submitted to: U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number 2010-031-00; Contract Number 53238.

Washington Dept. of Fisheries and Washington Department of Wildlife [WDF andWDW]. 1993. Washington State Salmon and Steelhead Stock Inventory.Appendix Three: Columbia River Stocks. Washington Department of Fisheries,Washington Department of Wildlife. 580 pp.

4. Revegetation

The overall objective of the revegetation project was to plant native trees and shrubs in Rock Creek riparian zones. Species chosen for revegetation include alder *(Alnus spp.),* black cottonwood *(Populus trichocarpa),* ponderosa pine *(Pinus ponderosa),* red-osier dogwood *(Cornus stolonifera),* chokecherry *(Prunus virginiana),* wild rose (*Rosa sp.),* and coyote willow *(Salix exigua).* All of the plant species selected are native to the Rock Creek watershed; these plantings will increase the vegetative diversity of the area. The riparian plantings will aid in protecting streambanks, reducing bank erosion, providing habitat complexity, and decreasing surface water temperatures through increased riparian cover.

Tree planting and weed removal

Site visits were conducted throughout the Rock Creek subbasin to characterize the native vegetative community in various riparian areas. Large and healthy willow bunches were identified for future willow-cutting sites. Rock Creek subbasin instream flows become intermittent through the summer months, and sufficient soil moisture is essential for the survival and growth of trees and shrubs. Topographic maps and orthophotos were used to identify where springs and groundwater may be available to support plantings, and revegetation sites were chosen based on their proximity to these sites and soil moisture. Land ownership was an additional criterion. Tribally owned sites received higher priority for revegetation due to uncertainty of ownership and land management on some non-tribal properties along the creek, which could affect long-term success of the plantings. Site preparation was conducted prior to tree planting with brush and debris clearing. Trees were planted during late February and early March when the soil was saturated to allow for root establishment and growth. Weed mats were tacked onto the earth below the trees with pins, and mulch placed on top to assist trees in maintaining water storage. Star thistle (*Centaurea solstitialis)*, bull thistle (*Cirsium vulgare*), and other invasive weeds were hand-removed from tree planting sites and adjacent areas to prevent encroachment. Follow-up weed control occurred on an annual basis.

Revegetation efforts began in the spring of 2008 and continued through 2012. A total of 1300 trees, shrubs and willow cuttings were planted on 16.5 acres along the mainstem Rock Creek riparian corridor and the uplands immediately adjacent to the creek between RM 3.3 – RM 5.5. There are a total of five main planting sites, all located in lower Rock Creek: the Longhouse site (RM 3.34); Highway 8 site (RM 3.95); Canapu site (RM 5.05); Site 1 Trees (5.28); and Site 2 Trees (RM 5.5). The revegetation effort was concentrated between RM 3.95 to RM 5.5, and occurred on both sides of the creek. (See Figure 2.)

Trees were hand-watered once or twice weekly during the warm summer months for the first two years after planting. Weed treatments were performed annually on all 16.5 acres of the revegetated riparian area. Weeds were removed by hand and mechanical means (weed-eaters, etc.) in revegetated and adjoining areas to discourage encroachment into planting sites. No biological or herbicidal treatments were used. During post-planting site visits, very few trees and shrubs were observed that had been affected by beaver activity. The trees affected were not removed from the ground, and there was natural re-growth occurring at the base of the trees. The survival rate ranged from 50–70% based on annual observations the first two years after planting.

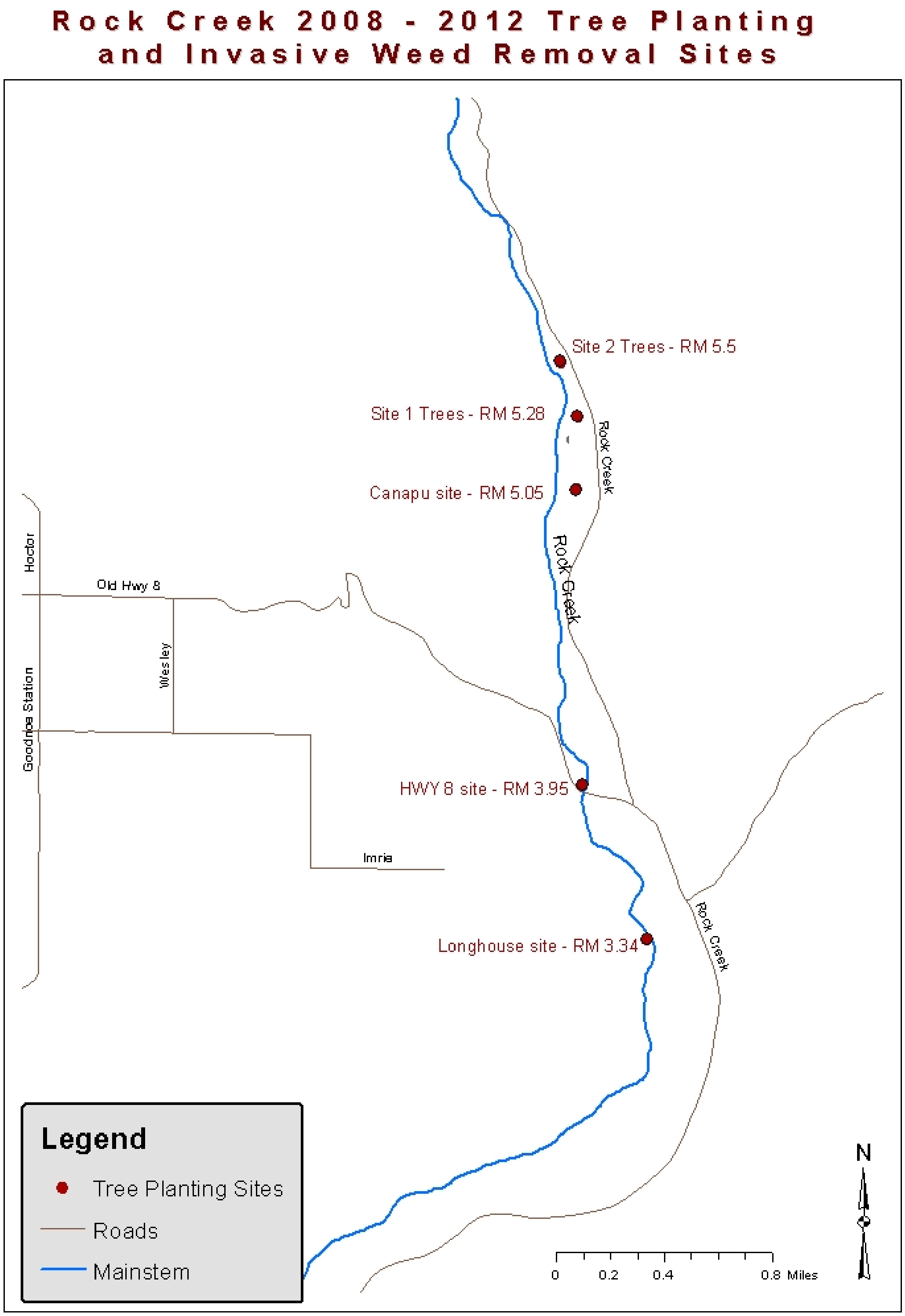

Figure 2. Tree planting and invasive weed removal sites in Rock Creek, 2008-2012.

Willow and tree nursery

The objective of this activity was to create a nursery of native willow cuttings (coyote willow, *Salix exigua*), collected from Rock Creek, to plant in containers for future planting opportunities in Rock Creek. Collecting and propagating willows from cuttings taken at sites throughout the subbasin would ensure that they were adapted to local conditions. From previous years' experience, the coyote willow had higher survival started in the nursery (from live cutting to root and stem development) and outplanted than through live-stake plantings.

Two hundred willow cuttings were collected from three sites within the basin for growing in containers. Coyote willow was collected from large, healthy bunches. Willows were taken back to the nursery and soaked in water for two weeks to stimulate root growth. A nursery was constructed to house the containerized willows. Rooted willow cuttings were planted in containers and watered 2-3 times per week.

Ponderosa pine, Oregon oak, and red-osier dogwood bareroot shrubs (total 30–40) are purchased from the local conservation district each year and planted in pots for the following years' tree planting. This allows trees and shrubs to establish roots and have higher success post-planting. Nearly 90% of the purchased bareroot plants survive in the nursery each year.

From 2008 through 2012, 200 live-stake willow cuttings were made each year and planted in the nursery. The annual willow survival rate in the nursery varied between 25% in the first year to 70% in subsequent years. The willows that survived previous years were planted out in the following spring. (Outplanted willow survival is included in the survival rate, above.) Willows were watered 2-3 times per week in the nursery during the warm summer months. Each year during the early spring months, additional willow cuttings were collected and planted in the nursery for future revegetation purposes.

Acknowledgments

We would like to take this opportunity to thank all those individuals and organizations that have helped contribute in some way to the Rock Creek project. A special thanks to private landowners for their cooperation and allowing access through their property for monitoring. The following Yakama Nation (YN) technicians assisted in collecting valuable fish and habitat information: Bronsco Jim Jr., Sandy Pinkham, Rodger Begay, Roger Stahi, Jeremy Takala, Alina George, and Sonya Jackson. Jeanette Burkhardt, YN Watershed Planner, provided assistance with collection of fish population and habitat data, and technical writing. Mike Babcock, YN Data Systems Manager, provided assistance with data management. Bill Sharp, YN Fisheries Research Scientist, provided assistance and management of the project. Brady Allen, Carrie Munz, and Ian Jezorek with United States Geological Survey (USGS) were cooperators with set-up of PIT-tag interrogation system (PTIS), collection of fish population and habitat data, PIT-tagging, and monitoring. Ken Luhan, microbiologist with the United States Fish and Wildlife Service (USFWS), provided pathogen analysis information. Andrew P. Matala and Shawn Narum, geneticists with Columbia River Inter-Tribal Fisheries Commission (CRITFC), provided steelhead genetics analysis information.

Appendix A: Documentation used in the Ecosystem Diagnosis and Treatment Model (EDT) for the Rock Creek Watershed.

Prepared by

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April 30, 2014

Contents

Introduction

This report summarizes the Ecosystem Diagnosis and Treatment Model (EDT) dataset for Rock Creek. In this project we rated 19 reaches with 45 environmental attributes per reach for current conditions and historical conditions. Over 800 ratings were assigned; however, empirical observations within each reach are not available for all of these ratings. Development of the remaining data was accomplished by expansion of empirical observations where available. Where empirical observations were not available, derived information was used. In some cases, where derived information was not available, expert opinion and hypothetical ratings were used. For example, if a maximum stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics, we then used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. In some cases, such as bed scour, no data was available for this basin. However, bed scour is related to peak flow, gradient, stream width, and confinement. Based on these observations, expert opinion was used to generate a bed scour estimate. For an explanation of the rationale behind each attribute rating, see the text below. For specific reach-scale ratings, monthly pattern shapes, and rating comment information, please contact the authors, or see the EDT database for Rock Creek, (*http://www.edt.icfi.com/edt/*).

Level 2 attribute definition and rationale

Hydrologic Characteristics

Hydrologic Regime

Hydrologic regime – natural

Definition: The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

Rationale: The Rock Creek headwaters originate on the southern slope of the Simcoe Mountains. The maximum elevation is approximately 4,700 ft, which is near the elevation of snow accumulation. The higher elevations in Rock Creek exhibit a snow-melt pattern. However, most of the watershed is lower elevation, and therefore we rated Rock Creek and its tributaries to be consistent with rain-on-snow transitional patterns. Therefore, all of the reaches were given an EDT rating of 2 for the historic and current conditions.

Level of Proof: Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Hydrologic regime – regulated

Definition: The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-intra-daily variation attribute).

Rationale: This attribute is not rated in the template condition, since there was no hydroelectric development. There is no evidence of change in the natural hydrograph, and these watersheds do not have artificial flow regulation. These watersheds were given an EDT rating of 0 for the historical and current conditions.

Level of Proof: Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Flow Variation

Flow: change in interannual variability in high flows

Definition: The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exist, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

Rationale: By definition, the template conditions for this attribute are rated as a value of two, because it describes the attribute rating for watersheds in pristine conditions. Direct measures of inter-annual high flow variation are not available for most basins. Peak flow can be increased due to the effects of roads; however road density in Rock Creek is relatively low, with 1.5 miles/mile^2 of road on average (Aspect 2004 page 5-21). However, only county roads were used for this estimate. A qualitative review indicates that the majority of roads in the watershed are non-county owned, thus the effects of roads are likely much greater than reported in Aspect (2004). Changes in ground cover (grazing, timber harvest) can also cause an increase in peak flows by reducing water infiltration. Therefore, we rated peak flows to be slightly higher than in the template conditions, with the effect being greater in the headwaters and reduced in the downstream reaches.

Level of Proof: Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Empirical information was used to estimate the current ratings for this attribute for the mainstem and derived information was used for the tributaries. The current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

Flow: changes in interannual variability in low flows

Definition: The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exist, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

Rationale: By definition, the template conditions for this attribute are rated as a value of two because this describes the attribute rating for watersheds in pristine conditions.

There are historical oral reports of substantial reductions in current low flow for Rock Creek compared to historic low flows (Harvey, personal communication). Water withdrawals, from wells and spring development for livestock and domestic use occur and have increased in the watershed. However, the unregulated and/or unmetered well water withdrawals relative to the inflow are unknown. Estimated annual self-supplied residential use ranges from 63 to 1,028 acre-feet/ year (Aspect 2004, pages 3-48 and 3-49). Cumulative recorded surface certificates and permits in Rock Creek total 6.0 acre-feet/year (Aspect 2004, page 3-31). Considering that Rock Creek receives 13 mean annual inches of precipitation per year, the combined water withdrawals likely influence summer low flows. Other probable reasons for lower summer flow include downcutting of streams in the headwater reaches, disassociation of the stream from its floodplain in portions of intermittent channels throughout Rock Creek, and changes in vegetation and soil structure in the uplands. Introduced walnut trees that are the primary riparian vegetation in portions of Rock Creek potentially consume greater amounts of water than native vegetation; however, we were unable to find evapotranspiration rates of walnut trees relative to those of native riparian vegetation. Based on the reasoning above, we assumed greater than 20 percent and less than 50 percent reduction in the 45 or 60-day consecutive lowest average daily low flow for Rock Creek, which is an EDT rating of 3. However, a more thorough and peer-reviewed study of the reasons for reduced summer flows is likely warranted.

Level of Proof: Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. The geomorphic survey (YN 2014) assessed the increasing unmetered well development over time. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Flow: intra-daily (diel) variation

Definition: Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

Rationale: By definition, the template conditions for this attribute are rated as a value of 0 because this describes the attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff and hydroelectric development in the basin. There are no major metropolitan areas in this watershed with large areas of impervious surfaces.

Level of Proof: Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute in the remaining reaches, and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Flow: intra-annual flow pattern

Definition: The average extent of intra-annual flow variation during the wet season: a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with percent total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

Rationale: By definition, the template conditions for this attribute are rated as a value of 2 because this describes the attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in this watershed. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in inter-annual variability in high flows (Larry Lestelle, Mobrand, Inc., personal communication). The stream is likely more flashy now due to loss of beaver and beaver ponds, changes in forest canopy and ground cover, and compaction of soils by cattle grazing in the uplands. However, this was estimated to be a minor affect, which is reduced in downstream reaches. Downstream of Squaw Creek the intra-annual flow pattern was estimated to be the same as during historic conditions.

Level of Proof: Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

Stream Corridor Structure

Stream Morphology

Channel length

Definition: Length of the primary channel contained within the stream reach. Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

Rationale: The current length of each reach was calculated using ArcGIS Measure Tool. The historic channel lengths of each reach were estimated to be the same as the current channel lengths. This information is provided in Table 2 and in the Rock Cr. stream reach editor available online.

Level of Proof: Derived information (ArcGIS) was used to estimate the current ratings for this attribute for all reaches, and the level of proof has a strong weight of evidence in support but is not fully conclusive, especially for historical length.

Channel width – month minimum width

Definition: Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

Rationale: Representative reaches in the Rock Creek watershed were surveyed by YN in 2008 - 2012. In addition, habitat surveys were completed by USGS and the YN during the low-flow period (September) in 2010 through 2012 where wetted widths of perennial pools were recorded. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Minimum channel width has likely been reduced from historic conditions similar to the reduction in summer low-flow conditions. Stream widths are narrower than historic conditions for the same reasons as described for the changes in interannual variability in low flows.

Because portions of Rock Creek become intermittent, with perennial pools and dry riffles during the low-flow period, low-flow stream widths were further modified to estimate the actual wetted area during that time period. This was done by calculating the average pool width, and then reducing this by multiplying by the percent of the length that was wetted. The low-flow widths were reduced, while keeping the stream length the same to estimate habitat area available for rearing during the summer more accurately. The minimum channel width is applied using a monthly rating that adjusts the available rearing area to its minimum during August, September, and October.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and derived information was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion, and the level of proof has theoretical support with some evidence from experiments or observations.

Channel width – month maximum width

Definition: Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

Rationale: Wetted widths corresponding to average high flows were not routinely measured as part of the YN habitat surveys, but were measured during Wolman pebble counts conducted by the YN. Measurements of channel width made using ArcGIS Measure Tool and orthophotos were used to determine average maximum stream width for each reach. Historical reaches were assigned the same value as the current condition for all reaches. Review of General Land Office (GLO) cadastral survey notes from the 1860s confirms that, in the few reaches where they reported it, channel widths were similar to the current widths.

Level of Proof: A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, we expanded current empirical observations, and the level of proof has theoretical support with some evidence from experiments or observations.

Gradient

Definition: Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

Rationale: The average gradient for each stream reach (expressed as percent gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. GIS Digital Elevation Models (DEMs) were used to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradients were assumed to be the same as current.

Level of Proof: Derived information (ArcGIS) was used to estimate the current and historical ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive, especially for historical length.

Confinement

Confinement – natural

Definition: The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankfull channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

Rationale: Confinement ratings were estimated using ArcGIS DEM and orthophotos to determine flood plain and bankfull channel width.

Level of Proof: Derived information (ArcGIS) was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Confinement – hydromodifications

Definition: The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in each reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

Rationale: In the historic condition (prior to manmade structures), reaches were fully connected to the floodplain. By definition, the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydromodification consists of roads and diking in the floodplain. The YN conducted a geomorphic survey, and the YN and USGS conducted a stream habitat survey. The personnel that conducted these surveys provided professional judgment to assign EDT ratings. In general, hydromodifications were uncommon, with the exception of some diking that is present in the reach upstream of Luna Gulch, and streamside roads and bridges in several reaches (largely downstream of Bickleton Bridge).

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Habitat Type

Habitat Types

Definition:

Backwater pools are the percentage of the wetted channel surface area comprising backwater pools.
Beaver ponds are the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.
Primary pools are the percentage of the wetted channel surface area comprising pools, excluding beaver ponds.
Pool tailouts are the percentage of the wetted channel surface area comprising pool tailouts.
Large cobble/boulder riffles are the percentage of the wetted channel surface area comprising large cobble/boulder riffles.
Small cobble/gravel riffles are the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
Glides are the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1 percent gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

Rationale: The USGS and YN surveyed reaches RC2, RC3, SQ1, SQ2, RC4, LG1 (lower 0.5 miles), RC6, and BG1 in 2008-2012. The USGS and YN surveyed reaches RC8, QZ1, and RC9 in 2010 and reaches RC2, RC3, SQ1, SQ2, RC4, RC5, RC6, and RC7 in 2010, 2011, and 2012. Bureau of Land Management surveyed reaches RC8, QZ1, and RC9 in 1986 and 1987. Habitat type composition was measured or estimated during these surveys. WPN (2009) conducted habitat surveys in many of these reaches; however the information was not presented in a way that it could be incorporated. Also, the percent pool recorded in WPN, 2009 was significantly greater than the BLM or USGS surveys (50 percent vs. 10 percent and 12 percent for BLM and USGS respectively), and therefore considered to be inaccurate. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys or averages of representative reach surveys with similar habitat, gradient and confinement. Comments are provided in the stream reach editor.

In general, for historical conditions we assumed that the percentage of pools was slightly higher than the current percentage, but probably not much different than historic conditions. We believe there has been a slight loss of pool habitat (5-10 percent) and some loss in beaver pond habitats. The majority of the habitat is large cobble riffle with very little small substrate. We assumed that pool tail-outs represent 15 – 20 percent of pool habitat, which is the current range from WDFW surveys. Because steelhead are modeled to use pool, riffle, and glide habitats equivalently, changes in this parameter do not substantially affect the model results (Greg Blair, ICFI, personal communication).

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. The level of proof for current ratings has a strong weight of evidence in support, but is not fully conclusive. We expanded empirical observations and used expert opinion for historical information, and the level of proof has theoretical support with some evidence from experiments or observations.

Habitat types – off-channel habitat factor

Definition: A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

Rationale: When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches. An EDT rating of 0 was assigned to tributary and higher gradient channels, a rating of 0 to 1 for B channels, while low gradient reaches RC2, RC3, SQ1, RC4 and RC6 were assigned EDT ratings of 1 to 2 percent for the current rating and 1 to 3 percent for the historical rating.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

Obstructions

Obstructions to fish migration

Definition: Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

Rationale: Falls and culverts were identified based on local knowledge and surveys conducted by Greg Morris, YN fish biologist, in 2008. All falls and culverts were assumed to have 100 percent passage in the winter months, and 0 percent passage from July through October during the low flow period. The exception to this is the falls at river mile 20.7, which is modeled to be the end of anadromous access and have 0 percent passage during all months.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Water withdrawals

Definition: The number and relative size of water withdrawals in the stream reach. This attribute identifies risk of a fish species being entrained or injured by screening or other structures associated with withdrawals of water from stream courses.

Rationale: No water withdrawals occurred in the pristine condition. There are water rights in the mainstem of Rock Creek for a total of 6 acre-feet/year (Aspect 2004, page 3-28). However, we know of no screen or diversion being used in the mainstem that would be a risk to a fish species being entrained or injured by screening or other associated structures. Therefore, the current ratings are the same as the pristine condition.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Riparian and Channel Integrity

Bed Scour

Definition: Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Rationale: While significant bed load movement occurs in Rock Cr. during flood events, there was not much evidence of scour, when assessed during a geomorphic survey of Rock Creek. The bed is highly armored, and bed scour was not likely different from historic conditions (Will Conley, YN hydrologist, personal communication). No bed scour data was available for this subbasin. Historic bed scour ratings were assumed to be the same as current ratings.

Level of Proof: Expert opinion was used to estimate the current and historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations.

Icing

Definition: Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can, under some conditions, have long-term beneficial effects to habitat structure.

Rationale: These watersheds are rain-on-snow dominated. Anchor ice and icing events are likely to be rare based on elevations in the watersheds of interest. Some anchor ice has been observed to occur infrequently, likely having little or no impact to physical structure of stream, in-stream structure, and stream banks/bed. Therefore, EDT ratings of 1 were assigned to all reaches in the historical and current condition in the lower reaches. Rating of 2 was assigned to the upper reaches (upstream of Bickleton Bridge) due to higher elevation and the observation of anchor ice during the winter of 2014.

Level of Proof: Derived information was used to estimate the ratings for this attribute, and the level of proof is theoretical with some evidence of support.

Riparian

Definition: A measure of riparian function that has been altered within the reach.

Rationale: By definition, the template conditions for this attribute are rated as a value of zero because this describes the attribute rating for watersheds in pristine conditions.

Much of the current riparian condition is likely similar to historic conditions. This is particularly true upstream of Bickleton Bridge. However, the riparian condition is degraded in portions of the downstream reaches. Factors that have degraded the riparian condition include cattle grazing and exotic plant species within the riparian area. Exotic plant species include reed canary grass, Himalayan blackberries, and allelopathic walnut stands which are diminishing plant community/diversity and affecting riparian function when compared to historic conditions.

Level of Proof: There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations.

Wood

Definition: The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard Timber Fish Wildlife (TFW) definition as those > 50 cm diameter at midpoint.

Rationale: Template conditions for Rock Creek were rated based upon gradient, confinement, and likely riparian habitat type (forested areas would be expected to have more LWD than lower elevation sage) to estimate historical LWD loading. We believe it is likely that there are similar but slightly reduced LWD densities currently as occurred historically. To determine current EDT ratings we used published data from WPN, 2009 and unpublished data from LWD surveys conducted by the YN. The YN counted wood pieces visually estimated to be >10 cm diameter and 2 m length within the wetted width in 2012 in reaches RC2, RC3, SQ1, and RC6.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, derived information was used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Sediment Type

Fine Sediment (intragravel)

Definition: Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1 mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

Rationale: Results from Wolman pebble counts conducted by the YN and WPN (2009) were used to populate this attribute in appropriate reaches. Roads are known to increase sediment input into streams. Aspect (2004) reports the road density in Rock Creek to be relatively low, ranging from 1.23 mi/mi^2 in Luna Gulch to 2.04 mi/mi^2 in upper Rock Creek (Aspect 2004, page 5-20). However, it appears that only county roads were modeled for this estimate. A qualitative review indicates that the majority of roads in the watershed are non-county owned, thus the effects of roads are likely much greater than reported in Aspect (2004). However, the actual road density (including forest and private roads) is still not expected to significantly increase EDT fine sediment rating. The coarse scale (1:100,000) of model inputs and limited field assessment used for modeling sediment input in WPN (2009) are unlikely to have accounted for segments with disproportionately high sediment contribution. WPN (2009) estimated average annual sediment input from soil creep to be 5,950 tons/year (p. 45). They estimated 1,000 tons/year from cultivated land, but this was based on buffering 1:100,000 stream hydrography by 1000 feet and excluding areas beyond this. Given the likelihood of rilling and other unmapped channelized sediment flow paths, this number is likely to be an underestimate. They estimated 370 tons/year from road surface erosion with 93 miles of hydrologically connected roads (WPN 2009 page 49). It is unclear if sediment produced from cut-slope, ditch, or mass wasting was taken into account. It is also unclear if the inputs to the sediment model included the timing and intensity of precipitation or vegetation/crop cover. Although the information available was likely inaccurate, we did not conduct a separate assessment for the data inputs into the EDT model, as visual estimates of fine sediment does not appear to be excessive in Rock Creek.

Level of Proof: Expert opinion was used to estimate the historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations. Derived information was used to estimate the current ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations

Embeddedness

Definition: The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average percent) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

Rationale: Peterson et al. (1992) estimated fines to be 6 percent to 11 percent in the template (pristine) condition, which is an EDT rating of 1. Under these same conditions, we assumed embeddedness was less than 10 percent, which corresponds to an EDT rating of 0.5.

WPN (2009) and YN conducted Wolman pebble counts in some reaches and noted embeddedness. Embeddedness was estimated within riffles in Rock Creek to be 5 to 25 percent in 40 sites, 25 to 50 percent in 65 sites, and 50 to 75 percent in 18 sites (WPN 2009 page 34). However, the WPN (2009) information was not displayed by reach, or in a format that could be used for the EDT model. Also, these results seemed inaccurate when compared with USGS and YN field observations and geomorphic surveys. A geomorphic survey has been underway by the YN in 2014 (Will Conley, YN hydrologist, personal communication). Preliminary information from this survey was used to populate the EDT model for this attribute. In general, embeddedness of the substrate in Rock Creek was low, with less than 25 percent of the surface of cobble and gravel substrates covered by fine sediment. In most reaches, the model inputs for this value were less than 15 percent of the surface of cobble and gravel substrates covered by fine sediment.

Level of Proof: A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations.

Turbidity (suspended sediment)

Definition: The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids; hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/L. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$, where, X = duration in hours, Y = mg/L, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

Rationale: Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. An EDT rating of 1.0 was assigned to all tributary and mainstem reaches.

Turbidity (mg/L) from water quality monitoring was conducted by USGS in 1965 and 1966. They reported suspended sediment concentrations ranging from 263 to 1,320 mg/L when flow ranged from 880 to 1,810 cfs. Turbidity was also measured by the Central Klickitat Conservation District (CKCD) and YN during monthly water quality measurements, but not during high flow/ high turbidity times. Since these were grab samples, the duration of turbidity values was unknown. Using SEV index for the USGS records and assuming short duration (1-24 hours), these values yield SEV index of 6.7 to 8.3. This yields an EDT rating of 1.2. Therefore, for current and template conditions, mainstem and tributary reaches were rated as 1.2.

Level of Proof: A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations.

Water Quality

Temperature Variation

Temperature – daily maximum (by month)

Definition: Maximum water temperatures within the stream reach during a month.

Rationale: The CKCD, USGS, and YN placed thermographs (temperature loggers) in various locations within the Rock Creek watershed. Mainstem and tributary reaches with thermographs were RC2, RC3, SQ1, SQ2, RC4, LG1, RC6, RC7, QZ1, BX1, and RC9: This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce the monthly pattern. We assumed the monthly pattern to be the same for template and current conditions.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity. If temperature loggers were mid-reach, we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

Historical maximum stream temperature data is limited in Rock Creek. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens, decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary processes transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and groundwater inflow. Historical riparian conditions along the headwater stream environments in Rock Creek and its tributaries consisted of old growth forests of ponderosa pine and oak. Currently, most headwater riparian areas are dominated by immature forest. Lower flow from changes in soil structure and vegetation and groundwater pumping allows the water to warm more than historically. Therefore, on average, historical maximum temperatures should be lower than current temperatures.

Level of Proof: A combination of derived information and expert opinion was used to estimate the historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive.

Temperature – daily minimum (by month)

Definition: Minimum water temperatures within the stream reach during a month.

Rationale: The YN placed temperature loggers in various locations year-round in 2008-2013. Reaches with thermographs are: RC2, SQ1, RC7, and above QZ3. Thermograph data was consolidated to number of days below 4 C and 1 C by month. It was then entered into an Excel spreadsheet provided by Chris Frederiksen of the Yakama Nation (Frederiksen, unpublished), which generates EDT ratings and monthly patterns. As with daily maximum temperatures, ratings were expanded into adjacent and similar reaches. Historic minimum temperatures were rated to be the same as current.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. Expert opinion was used to estimate historic ratings.

Temperature – spatial variation

Definition: The extent of water temperature variation within the reach as influenced by inputs of groundwater.

Rationale: Historically, there was likely significant groundwater input in some reaches. Currently, there are likely fewer groundwater inputs due to groundwater withdrawals and/or spring development. Given the degree of well and spring development, it is highly likely that some fraction of reduced flows is attributable to human modification. Higher gradient reaches of the tributaries higher in the watershed likely had less groundwater input. We found limited data on the current or historical conditions for groundwater inputs. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices and unregulated groundwater withdrawals.

Level of Proof: Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

Chemistry

Alkalinity

Definition: Alkalinity, or acid-neutralizing capacity (ANC), measured as milliequivalents per liter or mg/L of either HCO_3 or $CaCO_3$.

Rationale: Alkalinity (Hardness, HCO_3) in the historic condition was given the same value as the current condition. Current conductivity levels were measured by CKCD and YN. These measurements were used to rate these reaches. Alkalinity (mg/L) was not measured, but conductivity (µs/cm) was, and the following conversion developed by Ptolemy (1993) was used: ALK = 0.421* CON - 2.31. Reaches without data were rated based on similar or adjacent reaches where measurements were taken. Empirical estimates were available for RC2, RC3, SQ1, LG1, BG1 QZ4, and upstream of RC11. These estimates were expanded to adjacent reaches.

Level of Proof: A combination of empirical information, expansion of empirical information and derived information was used to estimate the current and historical ratings for this attribute, and the level of proof has theoretical support with some evidence from experiments or observations.

Dissolved oxygen

Definition: Average dissolved oxygen (DO) within the water column for the specified time interval.

Rationale: Dissolved oxygen in the template (historic) condition was assumed to be unimpaired with an EDT rating of 0. The YN and CKCD measured DO when conducting water quality surveys. Each water quality station had at least one DO measurement below the 8.0 mg/L standard. DO measurements below 8.0 mg/L occurred most commonly during the late-season months (August through October), when flows are lowest and the water most stagnant. (Aspect 2004 page 4-7)

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute, and the level of proof is thoroughly established.

Metals – in water column

Definition: The extent of dissolved heavy metals within the water column.

Rationale: Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Currently no toxicity to salmonids is expected due to dissolved heavy metals under prolonged exposure. However, we do not know of any dissolved heavy metal sampling that has occurred in this watershed,

Level of Proof: Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

Metals/Pollutants – in sediments/soils

Definition: The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

Rationale: Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Currently, all reaches were assumed to be at natural (background) levels.

Level of Proof: Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data, except in the reservoir reaches.

Miscellaneous toxic pollutants – water column

Definition: The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

Rationale: Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. The current conditions were assumed to be the same as the template condition. Current levels are unknown and we do not know of any testing for this attribute.

Level of Proof: Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

Nutrient enrichment

Definition: The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macronutrients that enrich streams and cause buildups of algae. These conditions, in addition to leading to other adverse conditions such as low DO, can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be taken when considering periphyton composition, since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

Rationale: Actual data (collected as chlorophyll a concentrations) for this attribute was unavailable. Historically nutrient enrichment did not occur because watersheds were in the “pristine” state. Most reaches were given the same rating as the historic condition as there was no evidence of increased nutrient levels. However, Luna Gulch has the highest nitrate levels in Rock Cr.(0.14 to 0.18 mg/L). Nirtate +Nitrite was 0.59 as measured by the EKCD. Luna Creek also has mats of algae in the summer.

This is likely due to agricultural practices in the watershed, and therefore was rated as having higher nutrient inputs than was historically present.

Level of Proof: A combination of expansion of empirical observations and expert opinion was used to estimate the current ratings for this attribute, and the level of proof has a strong weight of evidence in support, but is not fully conclusive. For historical information, this attribute is rated 0 by definition and the level of proof is thoroughly established.

Biological Community

Community Effects

Fish community richness

Definition: Measure of the richness of the fish community (number of fish taxa, i.e., species).

Rationale: Historic fish community richness was estimated from the current distribution of native fish in these watersheds; personal communications with professional fish biologists, conversations with YN elders, and other personnel familiar with fish behavior and habitat preferences. Current fish community richness was estimated from direct observation during USGS and YN electrofishing surveys from 2009 – 2012. Additional fish community information was available in WPN (2009), however, the report indicated that they observed longnose dace and speckled dace and that they did not observe bullheads or bridgelip suckers when conducting a snorkel survey. No longnose dace were ever identified by USGS and the YN when handling thousands of dace while electrofishing from 2009 to 2012 and brown bullhead and bridgelip suckers were collected in each year in some reaches. Therefore the species composition and distribution reported in WPN 2009 was not considered reliable and was not used.

There was uncertainty with historical fish species distribution. However, we used integer EDT rankings for this attribute, so the exact number of species present is less critical. In the majority of rankings the presence or absence of a few fish species in either the historic or current scenarios does not change the ranking. However, in a few instances the historical fish community richness ranking might change if new information is found.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information a combination of empirical observations, historical accounts, and professional opinion was used to estimate ratings and the level of proof has a strong weight of evidence in support but is not fully conclusive.

Fish pathogens

Definition: The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

Rationale: For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero.

The following is an excerpt from the USGS juvenile fish assessment report: “In general fish collected in Rock Creek and its tributaries were in good health. From fall of 2009 to fall of 2012, a total of 207 fish were submitted to the U. S. Fish and Wildlife Service’s Lower Columbia River Fish Health Center (LCRFHC). These samples included 120 *O. mykiss*, 27 coho, and 60 speckled dace (from reaches RC2, SQ1, SQ2, RC3, RC4, and RC6). While most of the fish were in good health, some fish diseases were detected. Parasites and diseases that were commonly observed by USGS in the field included: Neascus or blackspot (*Uvulifer ambloplitis*), copepods (*Salmincola californiensis*), and symptoms common to bacterial kidney disease (*Renibacterium salmoninarum*). These parasites were also confirmed by the LCRFHC. Other less common parasites and diseases that were detected by the LCRFHC include: *Nanophyetus salmincola*, unidentified digenetic trematodes, *Epistylis sp*., and *Henneguya salminicola*. Although diseases were detected in some fish, 165 (80 percent) of the fish submitted to LCRFHC appeared to be in good health with no parasites or diseases found.”

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

Fish species introductions

Definition: Measure of the richness of the fish community (number of fish taxa). Taxa here refers to species.

Rationale: By definition, the template conditions for this attribute are rated as a value of 0 because this describes the attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above). Because we have more certainty about the number of introduced fish in each reach, the data precision of this attribute was rated non-categorically.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, this attribute is rated 0 by definition and the level of proof is thoroughly established.

Harassment

Definition: The relative extent of poaching and/or harassment of fish within the stream reach.

Rationale: In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low; however there were known historical Native American home sites and seasonal family congregations in some reaches. The current attribute ratings were similar to, or slightly greater than template conditions. The increases from historic conditions were due to proximity of roads, bridges, or county and federal parks. In general, harassment is rated very low throughout the watershed.

Level of Proof: There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Hatchery fish outplants

Definition: The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

Rationale: By definition, the template conditions for this attribute are rated at a value of 0 because this describes the attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants. No fish outplanting currently occurs in Rock Creek; however, straying of out of basin steelhead is known to occur. We did not alter the rating based on straying steelhead.

Level of Proof: For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

Predation risk

Definition: Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant).

Rationale: By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Increases in exotic/native piscivorous fishes were considered when developing this rating. In general, reach RC2 was rated 3 due to the predation from native pikeminnow, and introduced smallmouth bass and brown bullhead. The presence of introduced bullfrogs *Lithobates catesbeianus* in reaches RC2, RC3, RC4, RC5, SQ1, and LG1 also increased predation risk. Further, anthropogenic impacts that have lead to channel instabilities, resulting in increased intermittency and habitat simplification, have increased the predation risk in the perennial pools in reaches RC2, RC3, RC4, RC5, RC6, RC7 SQ1, and LG1. Pool quality may or may not be reduced from historic conditions; however, we believe that increasing pool complexity will increase summer survival which is partially a basis for this rating.

Level of Proof: There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

Salmon carcasses

Definition: Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

Rationale: Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic steelhead, Chinook and coho salmon were given a rating of 2. Reaches with coho and steelhead were given a rating of 3. Reaches with only steelhead were given a rating of 4, since these fish are iteroparus (repeat spawners) and their carcasses are rarely found near the spawning areas. For the current condition, RC2 was given an EDT rating of 3, due to the presence of coho salmon; all other reaches were given an EDT rating of 4.

Level of Proof: A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this.

Macroinvertebrates

Benthos diversity and production

Definition: Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

Rationale: No direct measures of benthos diversity were available in the template conditions for these watersheds. We assigned an EDT rating of "1" and assumed that in the historic condition macroinvertebrate populations were healthy, diverse, and productive and in the natural/pristine state. Ratings of 2 were given to reaches RC2 and RC3 in the historical condition, due to likely warmer temperatures and reduced insect diversity on those reaches.

Macroinvertebrate samples were collected in 2009 and 2010 by YN Fisheries Biologist Greg Morris in Rock Creek and Squaw Creek. B-IBI Species- Genus analysis was conducted by Puget Sound Stream Benthos - ECO Anyalysts, Inc. Results were B-IBI scores in RC2 of 20 on 5/29/2010. B-IBI results in RC3 were 16 on 10/21/2009 and 18 on 5/29/2010. Results in SQ1 were 24 on 10/21/2009 and 36 on 5/29/2010. Results in RC7 were 32 on 8/31/2009 and 32 on 5/29/2010. These equate to attribute ratings of 3 in reaches RC2 and RC3, and ratings of 2 in the rest of the watershed.

Level of Proof: Expansion of empirical observations, derived information, and expert opinion were used to estimate the current and historical conditions and the level of proof is thoroughly established or has a strong weight of evidence in support but not fully conclusive.

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References Cited

Aspect Consulting LLC and Watershed Professionals Network. 2004. Level 1 Watershed Assessment WRIA 31 (Rock-Glade Watershed). Project No. 030009-001-01. Accessed: 2 May 2014 at http://www.klickitatcounty.org/NaturalR/FilesHtml/2008WRIA31/

Barbour, M.T., J.B. Stribling, and J.R. Karr. 1994. Multimetric approach for establishing biocriteria and measuring biological condition, pp. 63-77 in Davis, W.S. and T.P. Simon (eds), Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, CRC Press, Inc., Boca Raton, Florida.

Canale, G. 1999. BORIS – Benthic evaluation of ORegon rIverS. Draft report. Department of Environmental Quality Laboratory - Biomonitoring Section. Portland, Oregon.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59: 66-76.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley & Sons, Ltd., West Sussex, England.

Hawkins, C.P., and 10 coauthors. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18(6): 3-12.

Hyatt, T.L. and R.J. Naiman. 2001. The residence time of large woody debris in the Queets River, Washington, USA. Ecological Applications 11(1) 191-202.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessment of biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Karr, J.R., and E.W. Chu. 1999a. Biological monitoring: essential foundation for ecological risk assessment. Human and Ecological Risk Assessment. 3: 933-1004.

Karr, J.R., and E.W. Chu. 1999b. Restoring life in running waters—better biological monitoring. Island Press, Covelo, CA.

Konrad, C.P. 2000a. The frequency and extent of hydrologic disturbances in streams in the Puget Lowland, Washington. Ph.D Dissertation, University of Washington, Seattle.

Konrad, C.P. 2000b. New metrics to characterize the influence of urban development on stream flow patterns. The Washington Water Resource 11(4):3-6. Available: *http://depts.washington.edu/cuwrm/* (November 2004)

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society 129:262-281.

May, C.W., E.B. Welch, R.R. Horner, J.R. Karr, and B.W. Mar. 1997. Quality indices for urbanization effects in Puget Sound lowland streams. Water Resources Series Technical Report 154, Washington Department of Ecology, Seattle.

Mobrand L. E. 2002. Subbasin Planning with EDT- A primer. Mobrand Biometrics, Inc. Vashon, WA. Available: *http://www.mobrand.com/MBI/pdfs/Subbasin_planning.pdf* (February 2005)

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife. Information Report 97-4, Portland. Available: *http://oregonstate.edu/Dept/ODFW/freshwater/inventory/pdffiles/habmethod.pdf* (December 2004).

Morley, S.A. 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: restoration with a biological focus, Washington, USA. Thesis, University of Washington, Seattle.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Report TFW-F3-92-001, Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife, Olympia.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138; USDA Forest Service, Intermountain Forest and Range Experimental Station, Ogden, UT.

Ptolemy, R.A. 1993. Maximum salmonid densities in fluvial habitats in British Columbia. Pages 223-250 in Proceedings of the 1992 Coho Workshop, Association of Professional Biologists of British Columbia and North Pacific International Chapter of the American Fisheries Society.

Sedell, J.R., and F.H. Everest. 1991. Historic changes in pool habitat for Columbia River Basin salmon under study for TES listing. Draft report, December 1990. Corvallis, Oregon: USDA Forest Service, Pacific Northwest Research Station. 7 p.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006, Washington Department of Natural Resources, Olympia, 224 pp.

Watershed Professional Network (WPN). 2009. WRIA 31 Instream Habitat Assessment, . Grant No. G0900072 July 31, 2009.

Appendix B: A Literature Review of Anadromous Salmonid Habitat

Rock Creek, Klickitat County, WA

Mainstem Rock Creek upstream of the Highway 8 crossing.

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December 1, 2013

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Executive Summary

The Rock Creek subbasin encompasses approximately 223 square miles of south-central Washington State and drains to the Columbia River tributary approximately 12 miles upstream of John Day Dam. Though mean annual precipitation averages only 16 inches, and surface flow intermittency is common, salmonids rear in Rock Creek and its tributaries year-round.
Rock Creek was listed on the Washington State 303d list for water quality impairment due to high water temperatures in 1996. Steelhead (the anadromous form of *Oncorynchus myikss*) were listed as a "Threatened" species under the Endangered Species Act in 1999. A variety of reports have been produced over the years related, primarily, to one or both of these concerns. With growing interest in taking action to address watershed and fisheries concerns, it was prudent to conduct a review of existing information, characterize efforts, evaluate suitability of information to inform actions, and identify commonalities and/or gaps. This report summarizes twenty studies that have involved various degrees of primary data collection to characterize watershed conditions, stream temperature, salmon and steelhead populations, and/or habitat.
In general, evaluations have been coarse-scale, with poorly documented methods, light on primary data, and weighted heavily toward opinion. Where primary data collection has occurred, studies have not always been designed and/or implemented in ways that answer salient questions. Water quality studies have focused on shade as the primary cause of high stream temperatures though no evaluations of interruptions of hydrologic cycle have occurred. Mapping and modeling efforts have been based on 1:100,000 scale or coarser source data. Primary data have neither been linked to processes limiting salmonid production nor subpopulation strongholds. Few studies collected primary data and none have collected spatially continuous data. The result is an unclear representation of the historic, current, and/or desired Rock Creek watershed conditions.

Future work investigating location, quality, connectivity and fish utilization would be highly valuable to identifying limiting habitat factors. Of particular interest is the distribution of perennial habitats across multiple years and nature of groundwater relationships. Evaluation of stream and floodplain properties through time will provide insight on fluvial system behavior to assist suitability evaluation for potential enhancement actions. Identification of physical relationships and ecological interactions supported by primary data with well documented methods will assist development of geographic priorities and targeted actions.

Table of Contents

Introduction and Document Organization

Twenty existing documents addressing Rock Creek (Klickitat County, Washington State) physical habitat and fisheries resources with publication dates prior to June 2013 were identified and summarized. Sources include reports and plans prepared by various agencies and consultants and funded, primarily, by the Bonneville Power Administration (BPA) and Washington Department of Ecology (WDOE). Unpublished data and personal observations regarding fish-habitat relationships in the subbasin are also known to exist but were not included in this review unless they have been referenced in existing publications. A short summary of the effort and/or key findings of each document is grouped by thematic headings. Units are reported as originally published. Table 1 provides an inventory of summarized reports, indicates publication date and whether primary data is presented, and serves as an index for referring to subsequent tables. Remaining tables collectively provide a meta-inventory of subjects and data associated with reviewed studies.

Area of Interest

Rock Creek subbasin encompasses approximately 223 square miles of southeastern Washington State (Figure 1). Rock Creek flows into the Columbia River at river mile (RM) 230 approximately 12 RM upstream of John Day Dam.

Watershed Characteristics

Rock Creek drains 223 square miles of eastern Klickitat County in south-central Washington. Elevations range from 266 feet at the confluence with the Columbia River to 4,700 feet at the headwaters in the Simcoe Mountains. The basin is generally south-facing and drains the eastern end of the Simcoe Mountains as it transitions into the Horseheaven Hills. Estimates of average annual precipitation derived from Western Regional Climate Center station data range from 20 – 25 inches in the headwaters to less than 10

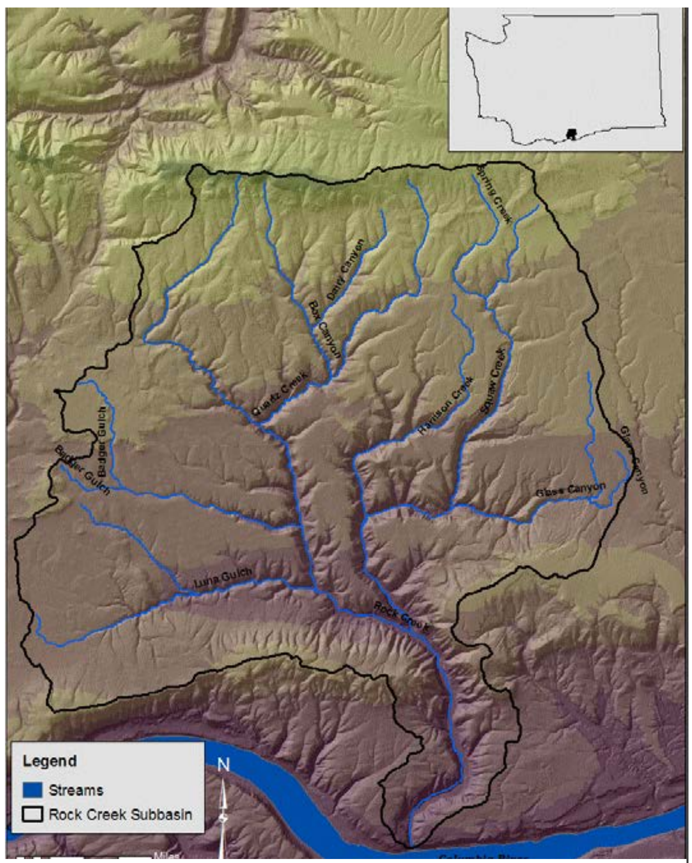

Figure 1. Rock Creek Subbasin located in Southeastern Washington State (Espirito, 2011).

inches in the lower elevations, with an overall mean annual precipitation of 16.2 inches (Aspect and Watershed Professional Network 2004). Major tributaries include Badger Gulch, Harrison Creek, Luna Gulch, Quartz Creek, and Squaw Creek.

The headwater tributaries and mainstem Rock Creek originate in the Simcoe Mountains and Horseheaven Hills, flow across a plateau which transitions from coniferous forest (Rock, Quartz, and Squaw) to shrub-steppe dominated vegetation (Badger, Luna, White, and Harrison) (Aspect Consulting 2004). The land use in the upland portions is managed forest, livestock grazing, and low-density residential homes. Stream gradients in this section are roughly 1%. Streams transition from the plateau through steep walled canyon sections (700-1500' deep), where gradients increase to 2-4% (Espirito 2009 and Lautz 2000). Land cover in the canyon sections is coniferous forest and mixed conifer-deciduous forest. Downstream of the canyon sections, streams emerge into wider alluvial valleys where the dominant land use is livestock grazing and gradients are between 1-2%, diminishing to less than 1% near the Columbia River confluence (Espirito 2009 and Lautz 2000). The average hillside slope for the Rock Creek subbasin is 36 %. By area, 36% of Rock Creek soils classify as National Resources Conservation Service (NRCS) Group D (slow infiltration, high runoff) and Group B and C (moderate and slow infiltration) soils collectively compose 57% (Aspect and Watershed Professional Network 2004).

Fisheries Overview

In order of prevalence, fisheries stocks in Rock Creek are fall Chinook salmon (*Onchorhynchus tshawytscha*), coho salmon (*O. kisutch*), summer steelhead (*O. mykiss*), resident rainbow trout (*O. mykiss*). Rock Creek steelhead are listed as "threatened" under the Endangered Species Act (ESA) as part of the Middle Columbia River steelhead Evolutionarily Significant Unit (ESU) (National Marine Fisheries Service 1999). Spawning surveys conducted in 2008-2010 observed coho and fall Chinook spawning during the fall and winter months in the lower 2.5 river miles. Surveys the same years documented that the majority of steelhead spawned in Rock Creek from RM 1- RM 13.5 and in Squaw Creek from RM 0 – RM 5.5 (Espirito 2013). Juvenile salmonids rear in Rock Creek and its tributaries year-round (Espirito 2009).

Summaries

Physical Habitat

Oakley, A. 1986. The Bureau of Land Management conducted a stream inventory on approximately 1.5 linear miles of Rock Creek near the confluence with Quartz Creek on May 20, 1986. General descriptions and notations on physical and biological attributes were recorded for half of the distance covered (7,920'). General descriptions of conditions concluded that "Rock Creek is well named" (1) for a typical high gradient steelhead type stream composed of small-boulder riffles. Banks were observed to be rocky and the amount of fine sediment did not appear

Table 1. Index of reviewed documents.

Document #	Author	Title	Publication Date	Primary Data	Document Location
1	Aspect Consulting	Rock Creek Water Quality Report (WRIA 31)	June-05	Y	Online
2	Aspect Consulting & ENVIRON International	Straight to Implementation Plan For Water Quality Improvement Rock-Glade Watershed	Mar-12	N	Online
3	Aspect Consulting & Watershed Professional Network	Level 1 Watershed Assessment WRIA 31 (Rock-Glade Watershed)	2004	Y	Online
4	Bauer, H.H., et. al.	Maps Showing Ground-Water Level in the Columbia River Basalt and Overliying Materials	1985	Y	Online
5	Brown, J.C.	Geology and Water Resources of Klickitat County	1979	Y	Online
6	Ehinger, W.	Evaluation of High Temperature in Rock Ck	Feb-96	Y	Online
7	ENVIRON International	Quality Assurance Project Plan for Canopy Closure and Channel Morphology Study for Rock Creek	Sep-10	N	Online
8	Espiritio, E.	An Evaluation of Steelhead Habitat Conditions of the Rock Creek Subbasin	May-10	Y	CWU
9	Espiritio, E.	2008 Annual Report - Rock Creek Fish and Habitat Assessment for the Priotization of Restoration and Protection	Aug-09	Y	Online
10	Espiritio, E.	2009 Annual Report - Rock Creek Fish and Habitat Assessment for the Priotization of Restoration and Protection	Sep-11	Y	Online
11	Espiritio, E.	2010 Annual Report - Rock Creek Fish and Habitat Assessment for the Priotization of Restoration and Protection	Mar-13	Y	Online
12	Lautz, K.	Salmon and Steelhead Habitat Limiting Factors	Jan-00	N	Online
13	Matala, A.	Genetic Evaluation of Stellhead Trout *(Oncorhynchus mykiss)* in the Rock Creek Watershed	Apr-12	Y	Online
14	NMFS	Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan	2009	N	Online
15	NMFS	Status Review of West Coast Steelhead from Washington	1996	N	Online
16	NWPPC	Draft Rock Creek Subbasin Summary	Mar-01	N	Online
17	NWPPC	Draft Lower Mid-Columbia Mainstem Subbasin Plan	Dec-04	N	Online
18	Oakley, A.	Summary of Rock Creek Stream Survey	May-86	Y	BLM
19	Watershed Professional Network	WRIA 31 Instream Habitat Assessment	Jul-09	Y	Online
20	WRIA 31 Planning Unit	Watershed Management Plan, Rock-Glade Watershed (WRIA 31)	Jan-08	N	Online

to be excessive. Pools were scarce and of poor quality where present, rearing habitat for juvenile fish appeared to be limited to around boulders and on stream margins.

Ehinger, W. 1996. As a response to the listing of Rock Creek as an impaired waterbody by the WDOE for exceeding water temperature standards, the Eastern Klickitat Conservation District (EKCD) and the NRCS deployed temperature monitors and conducted stream habitat evaluations in 1995. The stream habitat survey included quantitative and qualitative estimates of habitat attributes including stream substrate, riparian corridor width, and canopy cover. Observers concluded that lower Rock Creek shows “impacts from past grazing activity and episodic flood events, including lack of riparian cover and a shallow, braided stream channel” but showed little impact from current forestry or agriculture practices.

Watershed Professionals Network, 2009. Instream habitat was assessed by sampling randomly selected 100 meter sections, using both qualitative and quantitative methods. Reaches were delineated by major tributary junctions. A total of 19,703 meters of stream were sampled throughout the Rock Creek watershed which represents 15.7 % of the total habitat in the study area (WPN 2009). Target sampling extent was 10% of the total habitat by length, with a minimum of three, 100-meter long sample sections per reach. At the reach level, 14.5% of the total area was sampled on average, of which approximately 14% was dry when surveyed in fall and early winter 2008. Total sampled area for riffles, pools, and glides was 43%, 46%, and 11%, respectively. Pool volume averaged 8.2 m^3 per 100 m in the sampled area. The total estimated spawning areas for the Rock Creek basin is 59,604 m^2. Embeddedness and substrate composition was visually estimated and assigned to pre-defined categories. Tables 2-5 present a summary of sampling intensity and environmental characteristics. Percentage of surface fines was less than 20% of the substrate composition in all but one sampled segment (Squaw Creek Reach 4). Average large woody debris (> .51 meters in diameter) frequency was 1.7 pieces per 100m of sampled length. No natural barriers were identified over the course of the habitat surveys.

Sediment

Watershed Professionals Network, 2009. A screening-level sediment source modeling exercise was conducted utilizing two surface erosion models. General estimates were produced by the Water Erosion Prediction Project (WEPP) model (USDA 2008). The extent of stream bank extrapolated based on field observations (data collected during stream inventories) of 14% of the total stream length sampled, resulted in an estimate of total livestock damage by stream length of 8%. Field based observations that noted stream bank erosion is not widespread were used as input parameters to SEDMODL2 (National Council for Air and Stream Improvement 2002) a GIS based model which calculated average annual soil creep to be 5,397 metric ton per year. A United States Geologic Survey (USGS) 10 meter digital elevation model was utilized. Precipitation and other model inputs were not reported. Erosion from cultivated land was estimated using the WEPP model and applied to the area of land within 1,000 feet of a stream

Table 2. General sampling designs, intensity and timing of studies in Rock Creek.

Document #	Assessment Type	Sample Design	Sampling Unit	Cumulative Distance/Area	# of units	Time of Year
1	Water Temperature and Riparian Vegetation Assessment	convenience	point	-	13	year-round
2	Ground truthing of Aerial Photo Interpretation	-	point	-	-	-
3	Watershed Assessment	-	-	-	-	-
4	Groundwater Mapping	-	-	-	-	-
5	Geologic and Water Resources	-	-	-	-	-
6	Water Temperature and Habitat Survey	convenience	point	-	10	year-round
7	Study Design for Canopy Closure and Channel Morphology	Stratified	-	-	-	-
8	Habitat Evaluation Based on Modeling	Stratified	reach	not specified	28	not specified
9	Salmonid Population and Habitat Surveys	convenience	reach	not specified	specific to attributes	Summer & Fall
10	Salmonid Population and Habitat Surveys	Stratified	reach	not specified	20	Summer & Fall
11	Salmonid Population and Habitat Surveys	Stratified	reach	not specified	specific to attributes	Summer & Fall
12	Limiting Factors Analysis	-	-	-	-	-
13	Genetic Analysis	Stratified	each	not specified	112	not specified
14	Mid-Columbia Steelhead Recovery Plan	-	-	-	-	-
15	West Coast Steelhead Status Summary	-	-	-	-	-
16	Subbasin Summary	-	-	-	-	-
17	Mid-Columbia Subbasin Plan	-	-	-	14	-
18	Habitat Survey	convenience	reach	7920 ft	10	spring 1986
19	Instream Habitat Assessment	Stratified	reach	38,386 ft	-	winter 2008 & spring 2009
20	Watershed Management Plan	-	-	-	-	-

Table 3. Classes of channel morphology metrics sampled in Rock Creek. **Symbolization: –** not discussed, * = discussed but no data or analysis presented, **L** = identified as warranting further study, **D** = discussed based on existing data, **X** = physically measured or sampled and data or analysis presented.

Document #	Channel Width	Gradient	Bank Stability	Substrate Composition	Documentation of Channel Modifications	Barrier Identification
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	D	-	-	D	-	D
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	*	*	*	-
7	D	D	-	D	D	-
8	X	X	X	X	X	X
9	*	-	-	X	-	-
10	*	-	-	X	-	-
11	*	-	-	-	-	-
12	L	L	D	L	D	L
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	-	-	-	-	-	-
16	-	*	*	*	*	-
17	-	*	*	*	*	*
18	X	X	X	X	X	X
19	X	X	X	X	X	X
20	-	-	-	D	-	-

Table 4. Classes of habitat metrics sampled (pools, spawning, LWD, vegetation) in Rock Creek. **Symbolization: –** not discussed, * = discussed but no data or analysis presented, **L** = identified as warranting further study, **D** = discussed based on existing data, **X** = physically measured or sampled and data or analysis presented.

Document #	Pool Frequency	Pool Volume	Spawning Area	Riparian Corridor: Canopy Cover %	Riparian Corridor: Riparian Width	Riparian Corridor: Species Composition	Riparian Corridor: Riparian Condition	LWD Frequency	LWD Volume	Limiting Factors	Project Identification
1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	X	-	-	X	X
3	-	-	-	D	D	D	D	-	-	-	-
4	-	-	-	-	-	-	X	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	*	-	-	X	-	-	-	-	-	-	-
7	-	-	-	L	L	-	L	-	-	-	-
8	X	X	X	-	-	-	X	X	-	-	-
9	*	*	-	-	-	-	*	*	*	X	X
10	*	*	-	-	-	-	*	*	*	X	X
11	X	X	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	X	-	-	X	-
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	*	*	*	-	*	-
17	*	-	-	-	-	-	*	*	-	x	-
18	X	X	X	X	-	X	X	-	-	X	X
19	X	X	X	X	X	X	-	X	X	X	-
20	-	-	D	-	-	-	D	-	-	-	-

Table 5. Classes of water quality metrics sampled in Rock Creek. **Symbolization:** – not discussed, * = discussed but no data or analysis presented, **L** = identified as warranting further study, **D** = discussed based on existing data, **X** = physically measured or sampled and data or analysis presented.

Document #	Streamflow	Temperature	Dissolved Oxygen	Turbidity	pH	Conductivity	Nitrate	Fecal Coliform	Other Environmental Variables
1	X	X	X	-	X	X	X	X	-
2	-	X	-	-	-	-	X	X	-
3	D	D	D	D	D	-	D	-	-
4	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	X	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-
8	*	X	X	-	-	-	-	-	X
9	-	X	*	-	*	*	-	-	-
10	-	X	*	-	*	*	-	-	-
11	-	X	*	-	*	*	-	-	-
12	D	D	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-
16	D	*	-	-	-	-	-	-	-
17	D	*	-	-	-	-	-	-	-
18	X	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-
20	X	X	-	-	-	-	X	X	-

(buffer). The stream buffer layer was created from Washington Department of Natural Resources GIS coverage (1:100,000). Average annual sediment input to streams from cultivated land was estimated at 1,000 tons per year. Results should be regarded cautiously due to inherent model inaccuracies, coarse input data, and variation in actual crops, irrigation rates, and timing and intensity of precipitation events.SEDMODL2 model was also utilized to generate an estimate of the amount of surface erosion generated by roads. The SEDMODL2 model is an empirical road surface erosion model that determines which portions of a road network have the potential to drain to streams and generates an estimate of the annual sediment input to streams. The model input parameters are road width, gradient, type of surface material, ditch width, cutslope height, and percent vegetation cover. Values for these inputs were gathered from a one day sample of Klickitat County road conditions that covered 200 miles. The SEDMODL2 model estimated that within the Rock Creek subbasin, 93 miles of road are hydrologically connected, resulting in an average delivery of 370 tons of annual sediment input per year from surface runoff. This estimate does not take into account the contribution of sediment made by roads on private industrial forest lands or private agricultural lands.
Espirito, E. 2013. Beginning in 2008, channel substrate was monitored at three locations on mainstem Rock Creek. One riffle with suitable spawning substrate was selected in the vicinity of each of the following: Bickleton Hwy bridge (~RM 13.7), Squaw Creek confluence (~RM 8.2), and the Army Corps boat ramp (~RM 1.2). Sites were selected based on ease of access for annual sampling and sampling via Wolman pebble count (Wolman 1954). The average substrate size found at both the Bickleton Bridge and Squaw Creek site was small cobble from 2008-2010. The length of time sampling has been conducted (3 years) is not of sufficient duration for analysis and trend detection.

Streamflow

Aspect Consulting, 2004. The period of record for streamflow in Rock Creek is discontinuous. The United States Geological Survey (USGS) operated a gaging station from 1963-1968, located near the mouth at Roosevelt, WA. The mid-1960's are considered to be within a cool/wet climatic cycle of the Pacific Decadal Oscillation. After 1969, there was no streamflow gage in operation until 2007. The Washington Department of Ecology operated a gaging station from 2007-2012, located near the mouth at the old Hwy 8 bridge crossing. Continuous streamflow is typically only present near the confluence with the Columbia River from December through May each year. Although there are numerous springs mapped in the Rock Creek subbasin, groundwater discharges from the Wanapum Basalt combined with the alluvial substrate provide insufficient baseflow to sustain continuous surface flow in the lower reaches during the summer months. Neither streamflow statistics nor additional analysis was conducted.

Water Temperature

Ehinger, W. 1996. Rock Creek was placed on the Washington State 303 (d) (water quality impaired) list for temperature based on multiple instances of exceeding the 18ºC/64.4ºF threshold (non-anadromous waters) during field sampling in 1990 and 1991. In 1995-1996, WDOE and EKCD collected continuous water temperatures at ten monitoring sites (Table 2). The report stated, "temperatures observed in upper Rock Creek may be natural for a small creek in a hot, sunny summer climate. A small stream, such as Rock Creek, situated on a south facing slope is especially sensitive to overheating where riparian cover is low. The challenge lies in determining what portion of the temperature increase is the result of natural causes, and what portion arises from human activity". As a result of the temperature study a MOA between EKCD and WDOE was formalized to outline mitigation measures to be implemented and reporting requirements. The EKCD initiated a small scale revegetation effort along portions of Rock Creek and Squaw Creek, and began a long-term monitoring program of water temperature and other water quality parameters.

Aspect Consulting, 2005. Water temperatures have been monitored by EKCD at various sites since 1995. Klickitat County (KC) obtained WDOE funding in 2004 to organize and manage data resulting in a database utility called DataStream (a standalone user interface to data stored in Microsoft Access). Water temperatures sampled at 13 sites recorded by EKCD typically exceed the default state surface water standards throughout the Rock Creek watershed during summer months. The typical pattern for water temperature in the entire watershed is that daily maximum temperatures rise above the state standard 7-day average of daily maximum temperatures (DADMax) of 16ºC at the beginning of the summer (typically in May) and do not cool below the standard until the end of September. The lower Rock Creek stations typically exceed the standard for the longest period of time, and have the highest single day maximum temperatures. Water temperatures progressively increase in the downstream direction over most of the year.

Espirito, E. 2009. Yakama Nation has monitored water temperatures at 10 sites dispersed throughout the mainstem Rock Creek and its tributaries since 2008. Air temperature data is also collected at three of ten sites. Data summaries of water and air temperature confirm that a variety of regulatory and/or biologically-relevant thresholds are exceeded during specified time periods (week, month). At sampling sites where water is present year-round, water temperatures daily maximum temperatures rise above the State standard 7-day average of daily maximum temperatures (DADMax) of 16ºC in mid to late May and do not fall below the State standard threshold until mid-to-late September.

Espirito, E. 2013. The USGS in cooperation with the Yakama Nation deployed temperature loggers at 18 sites in Rock and Squaw Creeks during the months of July-Sept 2010. Temperature sampling was paired with fish surveys designed to generate population estimates. All 18 sites recorded water temperatures that exceeded 16ºC/60.8ºF (7DADMax), the WDOE threshold for stream health in salmonid bearing waters. Water temperatures at half of the sites exceeded 20ºC/ 68ºF, the WDOE threshold for stream health in non-salmonid bearing waters.

Other Water Quality

Aspect Consulting, 2005. Rock Creek was listed on Washington State's 2004 Candidate 303d list for impaired water quality based on elevated water temperatures. Shortly thereafter Klickitat County oversaw a water quality assessment intended to evaluate Rock Creek in comparison to established Washington State water quality standards. Grab samples were collected at 11 locations (8 in Rock Creek and 3 in major tributaries) on two different occasions. One sampling event was conducted under high flow (March 2005) and one was conducted under low flow (November 2004) conditions, no samples were taken under summer flow conditions. The results revealed measured nitrate concentrations to be more than an order of magnitude below the 10 mg/L State drinking water standard. Detected fecal coliform levels in surface water samples were below the "draft" state standard (200 cfu/mL) established at the time. Field observers attributed fecal coliform to livestock grazing in proximity to the stream. More intensive sampling over the course of a season would be necessary to document compliance with State water quality sampling standards which are based on statistical averaging of the data. For example, State standards require statistical averaging of fecal coliform data by season and must include 5 or more data collection events.

Espirito, E. 2011. The Yakama Nation has sampled dissolved oxygen, conductivity, and pH since 2008. Samples are periodic (3-10 times per year) at eight sites dispersed throughout the basin. Results or subsequent analysis have not been presented to date.

Riparian Vegetation

Aspect Consulting, 2005. Historic aerial photo-interpretation suggests aerial extent of vegetation across the Rock Creek valley bottom has been increasing since 1938 (earliest year of photo record). This was hypothesized to be a result of active fire suppression. However, there are localized riparian areas that have very little vegetative cover, and the stream channel is shallow, rocky, and braided. The study reviewed four sets of aerial photos collected from 1938-2002. The study did not account for two major floods that occurred during this photo period. The 1969 photos were taken roughly 4 ½ years after the 1964 floods and the 1996 photos were taken 6 months after the 1996 floods. The vegetative growth from 1938-1969 was not as significant as the 1969-1996 period. The study hypothesized that the 1964 floods eliminated some of the vegetative growth from the 1938-1963 period. The study evaluated total vegetative acreage in the valley bottom, irrespective of its proximity to the stream. Riparian shade and related effects on stream temperature were not evaluated.

Watershed Professionals Network, 2009. Riparian zones were characterized by measuring the width of the riparian zone, identifying dominant and subdominant species, and assessing canopy closure via visual estimate at the segment scale (100 m sample sections). Measurements and observations were conducted after leaf fall resulting in highly subjective canopy closure estimates as acknowledged by the author. Ocular estimates of canopy closure ranged from 0-46.7% percent, and averaged 20%. The point(s) from which (e.g.stream center line, top of bank, etc.) the ocular estimate was made were not reported. The most common species observed in the riparian zone were: alder, willow, walnut, and white oak.

Weed Removal

Espirito, E. 2011. Two hundred live-stake willow cuttings and 150 rooted trees (Ponderosa pine) were planted along 2.0 riparian acres of Rock Creek between RM 3.5 and RM 5.0 in 2009. Hand removal of invasive plant species was conducted within the planting sites and on adjacent upland areas to discourage encroachment. In addition, five fence enclosures were constructed to protect riparian plantings from trampling livestock, one third of the riparian plantings occur within these enclosures.

Extent of Exclusion Fencing

Aspect Consulting, 2012. Some reaches within Rock Creek have been fenced to exclude livestock from accessing the stream. A graphical representation showing the spatial extent of exclusion fencing was presented, but there are no figures provided on the number of miles fenced. It is unclear how this information was collected.

Fish Distribution, Abundance, and/or Productivity

Espirito, E. 2009, 2011 and 2013. Until 2013, limited published data regarding the spatial extent of fish distribution and the timing and duration of fish use within subreaches of mainstem Rock Creek and its major tributaries existed. In 2009, the Yakama Nation and USGS undertook a multi-year study to evaluate fish distribution, relative abundance, movement, and over summer survival and growth. The initial year of sampling was hampered by intermittent flows leading to increased stream temperatures that exceeded thresholds established by the National Marine Fisheries Service (NMFS) for the safe handling of juvenile fish. Conditions in subsequent years (2010 and 2011) permitted single-pass electrofishing to be conducted. The multi-year fish-habitat relationship study initiated by the USGS and the Yakama Nation in 2009 was continued in 2010. A stratified random sampling design was employed to inventory anadromous fish-bearing portions of Rock Creek that were physically accessible and/or where permission was granted by landowners. Habitat surveys were conducted to characterize the physical habitat prior to fish sampling efforts. During fish sampling a total of nine fish species were identified: steelhead/rainbow trout (*O. mykiss*), Coho salmon (*Oncorhynchus kisutch*), shorthead sculpin (*Cottus confuses*), speckled dace (*Rhinichthys osculus*), red sided shiner (*Richardsonius balteatus*), bridgleip suckers (*Catostomus columbianus*), northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), and brown bullhead (*Ameiurus nebulosus*).
O. mykiss were found to be abundant (1-12 fish/meter) in all areas sampled in Rock (RKM 2-RKM 21) and Squaw Creeks (RKM 2-RKM 8) in the spring of 2010, spring 2011 and fall 2011.

Table 5. Fisheries metrics sampled and analysis conducted on fisheries in Rock Creek. **Symbolization: –** not discussed, * = discussed but no data or analysis presented, **L** = identified as warranting further study, **D** = discussed based on existing data, **X** = physically measured or sampled and data or analysis presented.

Document #	Fish Presence/ Absence	Abundance Estimate	Population Estimate	Fish Movement	Distribution of Juveniles	Species Composition	Genetic Analysis	Redd Count	Distribution of Adults	Years Surveyed
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	X	-	-	-	-	-
3	D	-	-	D	-	D	-	D	D	2002-2004
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	D	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9		-	-	-	-	-	X	X	X	2008-2009
10	X	*	-	X	X	X	X	X	X	2009-2010
11	-	X	X	X	X	X	X	X	X	2009-2010
12	L	-	-	L	X	X	-	-	X	-
13	-	-	-	-	-	-	X	-	-	2008-2009
14	-	-	-	D	-	D	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	-	-	-	*	-	D	-	-	*	-
17	*	-	-	*	*	*	-	*	X	-
18	X	X	-	-	X	X	-	X	X	1986
19	X	X	-	-	X	X	-	X	X	2008-2009
20	D	D	D	D	D	D	-	D	D	-

Age-0 *O. mykiss* trout densities were greatest in the mid to upper reaches (RKM 8–RKM 19) of Rock Creek.

From 2009-2011 juvenile coho distribution and densities appear to vary more from year to year than *O. mykiss* densities). In 2009, juvenile coho were present in only 2 of 36 pools sampled (RKM 6.9-RKM 15.3), in 2010 juvenile coho were present in 7 of 31 pools; densities ranged from 0.5 fish/m to 15 fish/m. In contrast to the two previous years, juvenile coho were detected in 37 of the 39 pools sampled. Year to year variation in fish densities dictates multiple year sampling. Brown bullhead and northern pikeminnow were found only in the lowest most reach (Rkm2).

Watershed Professionals Network, 2009. A single pass, daytime snorkel survey was conducted in 2008 as part of the WRIA 31 Instream Habitat Assessment. The single pass survey consisted of sub-sampling delineated reaches and presents a one-day snapshot of fish presence in an unspecified portion of 2008. Date of the survey is not reported, but seems likely to have been springtime as mainstem Rock Creek reaches downstream of the Luna Gulch confluence were flowing continuously. Snorkel counts were not calibrated by means of alternative survey method (electrofishing). Observed numbers of fish were recorded by species and 100 mm size class (<100mm, ≥100<200mm, ≥200<300mm, and ≥300<400mm); however, snorkeler efficiency was not calibrated and therefore all fish numbers were relative. Greatest *O. mykiss* abundance was observed in Rock Creek between the mouth and Luna Gulch confluence. Total number of fish observed in the lower reaches constituted 90 % of the observed *O. mykiss* in the mainstem of Rock Creek and 71 % of the *O. mykiss* observed throughout the subbasin. Of the observed *O. mykiss* in the subbasin 8.2% were found upstream of the Bickleton Bridge in the portion of stream with continuous perennial flow. Given the intermittent nature of mainstem Rock Creek streamflow, the presence of *O. mykiss* year round indicates that life history strategies are present in the basin that can persist in a seasonal, spatially-intermittent environment.

Juvenile Migration

Espirito, E. 2009 and 2011. The Yakama Nation and USGS began PIT tagging juvenile *O. mykiss* within Rock Creek and major tributaries in 2009. Two instream PIT-tag arrays installed in 2009, one at confluence of Rock and Squaw Creeks (river mile 9) and the other in mainstem Rock Creek near the Longhouse (river mile 2.5). Squaw Creek confluence array consists of three stations: 1) Rock Creek downstream of the confluence, 2) Rock Cr.upstream of the confluence, and 3) Squaw Cr.upstream of the confluence. Fixed PIT tag interrogation systems (PTIS) facilitates the unique marking of individual fish and passive collection of individual fish data regarding timing and direction of movement. Subsequent recapture via electrofishing or other techniques can also inform questions regarding individual growth rates, survival, movement patterns, and reproduction. In the fall of 2009, 555 *O. mykiss* were tagged. Roughly a one-third of the PIT tagged fish were subsequently detected at one or more PTIS the following spring. A total of 182 fish were detected at the Squaw Creek PTIS and 172 of those were also subsequently detected at the Rock Creek Longhouse (PTIS) downstream. Juvenile steelhead outmigrated from Rock Creek from late March through mid-May. Multiple fish migrated past the Squaw Creek PTIS in the winter, reared for several months in lower Rock Creek between the Squaw Creek and the Longhouse, and then outmigrated the following spring. This movement pattern suggests that lower Rock Creek is used seasonally by *O. mykiss* prior to outmigrating as smolts. The PIT-tagging study was conducted from 2009 to 2012, with continued operation of the PTIS for several years thereafter; however, the full results from this study are not yet published. Continued PIT-tagging and analysis of PTIS detections will identify the primary areas of smolt productivity and staging.

Spawning Distribution

Espirito, E. 2009, 2011 and 2013. Since 2007, the Yakama Nation has implemented systematic surveys, by foot or by one-man pontoon boat, including the lowermost 2.5 river miles for spawning Chinook and Coho and lower 14 river miles for spawning steelhead. Fall Chinook surveys were conducted from mid-October - mid-December, coho surveys from late October – late February, and steelhead surveys from January – May (Table 6).

Table 6. Rock Creek observed salmonid redds 2007-2010 for surveyed reaches.

Spawning Year	Fall Chinook	Coho	Steelhead
2007	2	-	-
2007-2008	-	0	75
2008	2	-	-
2008-2009	-	0	45
2009	0	-	-
2009-2010	-	0	127
2010	6	-	-
2010-2011	-	2	287

Watershed Professional Network, 2009. Spawning surveys were conducted over the course of May12th and 13th 2009 by WPN personnel from the mouth of Rock Creek to Bickleton Bridge, excluding tribal lands. Stream flow was approximately 31-32 cfs (it is not reported whether this was measured or obtained) and the weather was sunny. The survey was conducted from the bank and was limited by vegetation and water depth. A total of 20 redds were identified with an additional 6 redds labeled "possible". and the weather was sunny. The survey was conducted from the bank and was limited by vegetation and water depth. A total of 20 redds were identified with an additional 6 redds labeled "possible".

Espirito, E. 2013. From September 2009 to June 2010, a total of 12 adult steelhead PIT-tagged as juveniles in other river basins were detected at fixed PIT-tag detection arrays in Rock Creek. These detections indicate that Rock Creek provides habitat to fish that were spawned elsewhere. These stray fish were tagged as juveniles at Lower Granite Dam, Hagerman Hatchery, and Irrigon Hatchery. Of the 12 steelhead, four were of hatchery origin and 8 were of wild origin. The adult steelhead entered Rock Creek beginning in January and continuing through April. Four of the 12 steelhead were not detected traveling upstream of the Squaw Creek PIT-tag detector near Squaw Creek and likely spawned in Rock Creek or upper tributary.

Espirito, E. 2013. From September 2009 to June 2010, a total of 12 adult steelhead PIT-tagged as juveniles in other river basins were detected at fixed PIT-tag detection arrays in Rock Creek. These detections indicate that Rock Creek provides habitat to fish that were spawned elsewhere. These stray fish were tagged as juveniles at Lower Granite Dam, Hagerman Hatchery, and Irrigon Hatchery. Of the 12 steelhead, four were of hatchery origin and 8 were of wild origin. The adult steelhead entered Rock Creek beginning in January and continuing through April. Four of the 12 steelhead were not detected traveling upstream of the Squaw Creek PIT-tag detector near Squaw Creek and likely spawned in Rock Creek or upper tributary.

Genetics

Espirito, E. 2013. In 2009, tissue samples (fin clip) for genetic analysis were collected from a total of seven sampling sites in mainstem Rock Creek and Squaw Creek. A total of 59 genetic samples were collected (30 Rock Creek and 29 Squaw Creek). In 2010-2011, a stratified sampling strategy was employed and 100 samples were collected. Twenty sampling sites were located in Rock Creek (RKM 1-RKM 35), Squaw Creek (RKM 0 –RKM 8), and one site in Luna Creek (RKM 0.1). The results of subsequent genetic analysis of the tissue samples performed by the CRITFC Hagerman, Idaho Genetics Lab indicated genetic similarity between collections of juvenile *O. my*kiss within the Rock Creek watershed and Snake River stocks. Additional studies suggest a high stray rate within middle Columbia River tributaries including the Deschutes and Klickitat Rivers (Matala 2012).

Fish Pathogens

Espirito, E. 2011. Fish tissue samples were collected from 2008–2010 to document pathogen presence in Oncorynchus mykiss and other unspecified resident fish species. A total of 234 juvenile *O. mykiss* and other resident species were collected for sampling. Tested samples were found to be in good health and no pathogens were detected.

Limiting Habitat Factor Identification

Espirito, E., 2011 and 2013. From 2008-2012 the Yakama Nation developed an Ecosystem Diagnosis and Treatment (EDT) model (ICF International) for Rock Creek RM 2 – RM 20.3, Quartz RM 0 – RM 3.8, Squaw RM 0 – RM 7.2 and Luna RM 0 – RM 2.2. Model inputs included a variety of metrics: wetted channel and high watermark widths, habitat type and length, large woody debris and log jam counts, confinement, riparian function, and embeddedness observations. A total of 27 attributes were collected in the field and incorporated into the model (Espirito 2010). The raw data collected on these attributes was not included in the reports nor has it been analyzed independent of the model. Model outputs are included as appendices in the reports but no interpretation or conclusions are offered.

Espirito, E. 2009 and 2011. An EDT model was developed to understand the effects of environmental attributes on life history stages for salmonid species. In Rock Creek, environmental and biological attribute data was collected in fifteen reaches. Data collected from field measurements was compiled and entered into the EDT model for analysis. The historic watershed conditions were derived from Government Land Office maps, air photos, and flow data. The EDT report presents basic results including: figures and tables identifying priority geographic areas, limiting life stages, and limiting habitat attributes. The report does not interpret results or make conclusions. A variety of non-specific restoration and protection recommendations were suggested including; restore and enhance natural riparian vegetative communities, eradicate invasive plant species from riparian areas, reconnect side channels, remove dikes, reconnect floodplain to channel, relocate or improve floodplain infrastructure roads.

Lautz, K. 2000. The limiting habitat factors analysis conducted by the Washington State Conservation Commission in 2000 was the first publication to identify factors limiting the production of salmonids and identify information gaps for the Rock Creek subbasin. The intent of the analyses was to have the findings “used by a locally based habitat project selection committee to prioritize appropriate projects for funding under the state salmon recovery program”. Little primary data existed for the subbasin at that time and report content was developed by a professional-opinion driven process that included individuals from [list agencies/entities here].

- Low or non-existent flows in all streams during the later summer, fall, and early winter will limit or preclude use by fall spawning adults and limit mobility of juveniles of all salmonid species.
- High stream temperatures in the lower portions of all streams during the summer and early fall will limit the mobility of juveniles of all salmonid species
- Grazing and trampling by cattle in and near stream banks has caused accelerated channel incision (entrenchment, downcutting) and resulted in a reduction in the quality and amount of available existing or potential fish habitat.
- Channel widening and obliteration of riparian zones caused by a 75 to 100 year flood event in 1996 has resulted in locally poor habitat quality and riparian condition. While there may be long term benefits (LWD recruitment, creation of complex habitat) as a result of this event, there may be opportunity to accelerate habitat recovery and improve stability against smaller, more frequent floods through channel and riparian restoration activities.
- Cattle watering at, or in the vicinity of, spring areas may have adverse impacts on water quality.
- Functional quality of riparian areas has been adversely impacted by grazing and forest practices in many locations throughout the watershed. Types of impacts include removal of or damage to riparian vegetation and compaction and erosion of stream banks and adjacent floodplain areas.

Conclusions

This report inventories and summarizes existing information on the historical and current state of anadromous salmonids and physical habitat in the Rock Creek watershed in south-central Washington State. Compiled information is intended to provide a baseline of existing information and focus future data collection efforts.

While a general lack of pertinent primary data limits conclusions, water temperature datasets appear to be the most robust. Stream temperature data collected by multiple entities since 1996 throughout the Rock Creek subbasin seem to agree that frequency and duration of maximum temperature standards generally increases downstream and occurs at all sites for some portion of the year. Seasonal distribution of exceedance is typically between May and the end of September, often continuously for lower elevation sites.

The following information gaps were identified:

a) location, quality, connectivity, and fish utilization of perennial base-flow habitat
b) surface flow/groundwater relationships
c) evaluation of stream and floodplain morphology through time

Several in-progress or recently completed studies may address gaps, but were not published in time for this review. This document should be supplemented with new information as warranted by the publication of new literature or the discovery of additional historical documents. Better methodological documentation would greatly facilitate future synthesis.

Literature Cited

Aspect Consulting, 2005, Rock Creek Water Quality Report, Water Resources Inventory Area 31, June 22, 2005.

Aspect Consulting and ENVIRON International, 2012. Straight to Implementation Plan for Water Quality Improvement Rock-Glade Watershed (WRIA 31), March 2012.

Aspect Consulting and Watershed Professionals Network, 2004. Level 1 Watershed Assessment WRIA 31(Rock-Glade Watershed). WRIA 31 Watershed Planning Unit. Project No. 030009-001-01.

Bauer, H.H., J.J. Vaccaro, and R.C. Lane, 1985. Maps Showing Ground-Water Level in the Columbia River Basalt and Overlying Materials, Spring 1983, Southeastern Washington. USGS Water Resources Investigations Report 84-4360.

Brown, J.C. 1979. Geology and Water Resources of Klickitat County. Washington State Department of Ecology Water Supply Bulletin No. 50. August 1979.

Ehinger, W. 1996. Evaluation of High Temperature in Rock Creek (Klickitat County), Ecology Report No. 96-308. February 1996.

ENVIRON International, 2012, Quality Assurance Project Plan for Canopy Closure and Channel Morphology Study for Rock Creek, WRIA 31, September 2010.

Espirito, E. 2010. An Evaluation of Steelhead Habitat Conditions of the Rock Creek Subbasin, A Thesis Presented to the Graduate Faculty Central Washington University, May 2010.

Espirito, E. 2009. Rock Creek Fish and Habitat Assessment for the Prioritization and Protection - 2008 Annual Report, BPA Project No. 1997-156-00, August 2009.

Espirito, E. 2011. Rock Creek Fish and Habitat Assessment for the Prioritization and Protection - 2009 Annual Report , BPA Project No. 1997-156-00, September 2011.

Espirito, E. 2013. Rock Creek Fish and Habitat Assessment for the Prioritization and Protection - 2010 Annual Report , BPA Project No. 1997-156-00, February 2013.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors: Water Resource Inventory Area 31. Washington State Conservation Commission.

Matala, A. 2012. Evaluation of steelhead trout (Oncorhynchus mykiss) in the Rock Creek watershed of the middle Columbia River Basin – Columbia River Inter-Tribal Fish Commission. April 13, 2012.

National Council for Air and Stream Improvement. 2000. Sediment Model 2. Version 2 release, December 2002.

National Marine Fisheries Service, 2009, Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan, November 30, 2009.

National Marine Fisheries Service, 1996, Status Review of West Coast Steelhead from Washington, Idaho, Oregon and California, August 1996.

National Marine Fisheries Service, 1999a. Updated Review of the Status of the Upper Willamette River and the Middle Columbia River ESUs of Steelhead (*Oncorhynchus mykiss*). January 12, 1999, NMFS-NWFSC Status Review Update Memo.

Northwest Power Planning Council, 2001, Draft Rock Creek Subbasin Summary, March 2, 2001.

Northwest Power Planning Council, 2004, Draft Lower Mid-Columbia Mainstem Subbasin Plan, December 8, 2004.

Oakley, A. 1986. Summary of Rock Creek Stream Survey, May 20, 1986.

United States Department of Agriculture, Agricultural Research Service 2008. Water Erosion Prediction Project. Version 2008.907.

Watershed Professional Network, 2009, WRIA 31 Instream Habitat Assessment, July 31, 2009.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. American Geophysical Union

WRIA 31 Planning Unit, 2008, Watershed Management Plan, Rock-Glade Watershed (WRIA 31), Prepared with assistance of Aspect Consulting and Watershed Professional Network, January 2008.

Appendix C. Water temperature monitoring

Table C-i. Monthly stream temperature summaries from 8 stream sites in the Rock Creek subbasin for the reporting period (1/1/2008 – 12/31/2013). All temperatures and ranges in degree Celsius (°C). Months in which no data were collected are omitted from the table. See description under temperature monitoring section in Report B for an explanation of metrics used.

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	8	31	5	31	0	0	0	0	0	0	0	4.5	1.6	1.0
February	29	0	28	0	22	0	0	0	0	0	0	0	6.7	2.7	1.9
March	31	0	25	0	9	0	0	0	0	0	0	0	8.0	4.2	2.6
April	30	0	19	0	1	0	0	0	0	0	0	0	12.3	5.7	4.0
May	31	0	0	0	0	0	0	19	3	0	0	0	18.4	5.9	3.5
June	30	0	0	0	0	0	0	30	15	6	5	0	22.0	4.9	3.6
July	23	0	0	0	0	0	0	23	23	23	23	0	22.1	4.6	3.5
August	31	0	0	0	0	0	0	31	31	31	31	0	21.8	4.3	3.0
September	30	0	0	0	0	0	0	30	22	11	0	0	18.3	3.4	2.8
October	31	0	0	0	0	0	0	12	0	0	0	0	16.0	3.3	2.1
November	30	0	2	0	0	0	0	0	0	0	0	0	12.7	3.7	1.7
December	31	0	21	0	18	0	0	0	0	0	0	0	9.2	2.7	1.1

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	2	31	1	29	0	0	0	0	0	0	0	5.8	3.0	1.1
February	28	0	28	0	26	0	0	0	0	0	0	0	5.9	2.9	1.7
March	31	1	25	0	14	0	0	0	0	0	0	0	8.3	4.0	2.4
April	30	0	6	0	1	0	0	0	0	0	0	0	13.2	5.3	3.7
May	31	0	0	0	0	0	0	19	8	4	3	0	19.1	5.4	4.1
June	30	0	0	0	0	0	0	30	30	20	14	0	19.1	4.7	3.4
July	31	0	0	0	0	1	0	31	31	31	31	7	23.1	5.1	4.1
August	31	0	0	0	0	2	0	31	31	31	31	5	23.6	4.2	3.4

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
September	30	0	0	0	0	0	0	30	28	22	19	0	20.7	3.4	2.8
October	31	0	0	0	0	0	0	12	0	0	0	0	15.2	2.9	1.8
November	30	0	1	0	0	0	0	0	0	0	0	0	10.2	2.3	1.7
December	31	5	30	0	30	0	0	0	0	0	0	0	6.2	1.9	1.0

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	24	0	17	0	0	0	0	0	0	0	6.0	1.7	1.0
February	28	0	10	0	5	0	0	0	0	0	0	0	7.7	2.7	1.6
March	31	0	12	0	1	0	0	0	0	0	0	0	10.1	4.9	3.1
April	30	0	5	0	0	0	0	1	0	0	0	0	12.8	4.9	3.4
May	31	0	0	0	0	0	0	20	0	0	0	0	16.0	5.2	3.0
June	30	0	0	0	0	0	0	30	10	4	1	0	18.9	4.2	2.9
July	31	0	0	0	0	0	0	31	31	26	25	0	21.3	4.4	3.5
August	31	0	0	0	0	0	0	31	31	29	28	0	21.1	3.6	2.9
September	30	0	0	0	0	0	0	30	29	3	0	0	18.6	3.1	2.3
October	31	0	0	0	0	0	0	14	3	0	0	0	17.2	2.7	1.8
November	30	0	9	0	8	0	0	0	0	0	0	0	12.3	2.4	1.5
December	31	1	30	0	26	0	0	0	0	0	0	0	5.9	1.8	0.9

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	25	2	17	0	0	0	0	0	0	0	7.0	2.6	1.4
February	28	4	23	2	19	0	0	0	0	0	0	0	6.4	3.5	1.8
March	31	0	25	0	9	0	0	0	0	0	0	0	9.6	3.6	2.4
April	30	0	9	0	0	0	0	0	0	0	0	0	10.5	5.9	3.7
May	31	0	0	0	0	0	0	24	0	0	0	0	14.3	5.7	3.6
June	30	0	0	0	0	0	0	30	11	0	0	0	18.0	5.1	3.2

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
July	31	0	0	0	0	0	0	31	31	18	11	0	19.9	4.2	3.1
August	31	0	0	0	0	0	0	31	31	31	31	0	20.7	3.6	2.9
September	30	0	0	0	0	0	0	30	28	18	15	0	19.2	3.0	2.2
October	6	0	0	0	0	0	0	6	0	0	0	0	15.7	2.0	1.0

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2012.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
May	28	0	0	0	0	0	0	28	0	0	0	0	17.5	5.6	3.6
June	27	0	0	0	0	0	0	27	10	0	0	0	17.7	3.8	2.5

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2013.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	26	0	0	0	0	0	0	8	0	0	0	0	14.9	5.8	3.6
May	31	0	0	0	0	0	0	31	8	0	0	0	18.4	5.5	3.4
June	30	0	0	0	0	0	0	30	24	8	4	0	21.6	4.7	3.0
July	31	0	0	0	0	0	0	31	31	31	31	0	22.3	3.5	2.2
August	31	0	0	0	0	0	0	31	31	31	31	0	20.1	2.0	1.5
September	30	0	0	0	0	0	0	30	21	18	16	0	19.2	1.7	1.3
October	31	0	0	0	0	0	0	7	0	0	0	0	12.5	2.7	2.0
November	30	0	10	0	10	0	0	0	0	0	0	0	10.4	3.9	1.5
December	4	1	4	0	2	0	0	0	0	0	0	0	7.5	3.9	2.

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	15	0	15	0	6	0	0	0	0	0	0	0	10.1	6.4	4.4
May	31	0	7	0	0	0	0	18	0	0	0	0	16.1	7.9	5.2
June	30	0	0	0	0	0	0	30	7	4	3	0	19.3	7.3	5.9
July	31	0	0	0	0	0	0	31	21	15	13	0	19.3	6.1	3.8
August	16	0	0	0	0	0	0	16	3	0	0	0	17.0	2.8	1.7
November	11	0	7	0	5	0	0	0	0	0	0	0	7.1	2.6	2.1
December	31	10	31	4	26	0	0	0	0	0	0	0	6.8	3.3	1.5

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	31	2	31	0	0	0	0	0	0	0	4.1	2.2	1.0
February	28	8	28	1	28	0	0	0	0	0	0	0	3.6	2.7	1.7
March	31	5	31	0	31	0	0	0	0	0	0	0	6.2	4.0	2.3
April	30	0	24	0	5	0	0	0	0	0	0	0	11.7	6.8	4.2
May	31	0	4	0	0	0	0	16	2	0	0	0	16.6	7.8	6.0
June	30	0	0	0	0	0	0	30	23	5	4	0	18.6	8.0	5.8
July	26	0	0	0	0	7	4	26	26	26	26	10	26.5	11.8	9.2
August	6	0	0	0	0	6	6	6	6	6	6	6	26.7	4.8	3.4
September	30	0	0	0	0	15	8	30	30	30	30	24	27.2	4.8	2.9
October	31	0	0	0	0	0	0	31	31	31	31	0	22.8	6.2	2.3
November	6	0	0	0	0	0	0	6	6	6	6	0	22.4	4.1	2.2
December	31	18	31	9	31	0	0	0	0	0	0	0	4.9	2.4	0.9

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	31	0	31	0	0	0	0	0	0	0	4.4	1.6	1.0
February	28	0	28	0	26	0	0	0	0	0	0	0	5.9	2.8	1.6

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
March	31	0	31	0	21	0	0	0	0	0	0	0	7.0	4.1	2.8
April	30	0	16	0	9	0	0	0	0	0	0	0	10.4	6.1	3.8
May	31	0	4	0	0	0	0	5	0	0	0	0	13.3	6.4	4.4
June	30	0	0	0	0	0	0	27	4	0	0	0	17.3	6.4	4.7
July	31	0	0	0	0	0	0	31	28	25	24	0	22.4	8.8	7.0
August	10	0	0	0	0	2	0	10	10	10	10	10	23.5	9.8	8.9
September	28	0	0	0	0	16	10	28	28	28	28	28	25.6	4.6	2.8
October	31	0	0	0	0	11	9	31	31	31	31	21	25.0	9.5	3.7
November	27	2	10	0	9	5	5	7	7	7	7	7	25.4	7.1	2.2
December	31	2	31	1	31	0	0	0	0	0	0	0	4.7	2.3	1.1

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	31	5	27	0	0	0	0	0	0	0	5.5	2.0	1.2
February	28	9	28	4	28	0	0	0	0	0	0	0	4.8	2.7	1.5
March	31	1	29	0	29	0	0	0	0	0	0	0	6.4	3.0	1.9
April	30	0	30	0	8	0	0	0	0	0	0	0	8.8	6.1	3.8
May	31	0	6	0	0	0	0	0	0	0	0	0	13.3	7.4	5.0
June	30	0	0	0	0	0	0	30	1	0	0	0	16.3	6.8	5.2
July	31	0	0	0	0	0	0	31	31	9	6	0	19.7	7.4	6.0
August	19	0	0	0	0	0	0	19	19	19	19	0	21.6	9.9	8.4
September	8	0	0	0	0	8	5	8	8	8	8	8	26.0	5.5	3.6
October	31	0	0	0	0	8	4	31	31	31	31	17	26.0	9.6	3.5
November	29	0	8	0	6	12	9	20	20	19	19	18	27.6	8.7	3.1
December	31	5	31	1	31	0	0	0	0	0	0	0	4.0	2.1	1.5

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2012.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	14	31	5	31	0	0	0	0	0	0	0	3.6	1.8	1.1
February	29	1	29	0	29	0	0	0	0	0	0	0	4.3	2.1	1.5
March	31	1	31	0	29	0	0	0	0	0	0	0	6.2	3.3	2.1
April	30	0	16	0	5	0	0	0	0	0	0	0	12.5	5.7	3.6
May	31	0	0	0	0	0	0	16	0	0	0	0	14.2	6.5	4.8
June	30	0	0	0	0	0	0	30	4	0	0	0	17.7	7.3	5.2
July	29	0	0	0	0	4	1	29	29	26	25	6	25.1	12.9	8.1
August	28	0	0	0	0	22	16	28	28	28	28	28	27.9	7.5	3.7
September	30	0	0	0	0	17	10	30	30	30	30	30	25.7	5.2	3.3
October	31	0	0	0	0	4	3	31	31	31	31	4	26.5	10.2	2.9
November	19	0	0	0	0	9	5	19	19	19	19	12	28.7	7.3	2.8
December	4	0	0	0	0	1	1	4	4	4	4	4	26.6	7.9	2.7

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	31	0	26	0	0	0	0	0	0	0	5.8	2.8	1.5
February	29	0	24	0	13	0	0	0	0	0	0	0	8.0	3.2	2.3
March	31	0	12	0	0	0	0	0	0	0	0	0	10.0	5.7	3.3
April	30	0	2	0	0	0	0	12	0	0	0	0	16.0	6.6	5.1
May	31		0	0	0	0	0	0	31	19	13	10	0	21.1	6.9
June	30	0	0	0	0	3	2	30	30	28	23	4	25.0	6.9	5.2
July	23	0	0	0	0	23	20	23	23	23	23	23	27.7	10.3	7.1
August	31	0	0	0	0	30	28	31	31	31	31	31	33.8	13.4	9.8
September	30	0	0	0	0	20	19	30	30	30	30	20	29.1	15.8	12.2
October	31	0	0	0	0	0	0	30	15	6	5	0	20.5	8.9	5.4
November	30	0	0	0	0	0	0	7	0	0	0	0	14.4	2.9	1.8
December	31	0	14	0	12	0	0	0	0	0	0	0	12.0	3.0	1.5

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	25	0	22	0	0	0	0	0	0	0	7.6	2.8	1.3
February	28	0	19	0	9	0	0	0	0	0	0	0	7.7	3.4	1.8
March	31	0	11	0	5	0	0	0	0	0	0	0	10.6	4.5	3.0
April	30	0	0	0	0	0	0	15	0	0	0	0	16.2	6.7	4.3
May	31	0	0	0	0	1	0	31	19	16	15	1	23.1	7.1	5.8
June	30	0	0	0	0	11	5	30	30	30	30	21	24.9	8.5	5.9
July	31	0	0	0	0	30	29	31	31	31	31	31	34.4	12.0	8.9
August	31	0	0	0	0	30	30	31	31	31	31	31	40.5	27.3	16.3
September	30	0	0	0	0	28	28	30	30	30	30	30	39.1	27.3	20.8
October	31	1	4	0	1	6	5	30	18	11	11	8	26.4	24.0	10.4
November	30	0	0	0	0	0	0	0	0	0	0	0	13.5	4.9	2.2
December	31	0	8	0	1	0	0	0	0	0	0	0	9.8	2.4	1.1

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	2	0	2	0	0	0	0	0	0	0	7.5	1.7	0.9
February	28	0	3	0	0	0	0	0	0	0	0	0	9.4	3.7	2.0
March	31	0	0	0	0	0	0	0	0	0	0	0	12.2	4.9	3.7
April	30	0	0	0	0	0	0	20	0	0	0	0	15.1	5.5	4.3
May	31	0	0	0	0	0	0	31	15	2	0	0	18.2	6.3	4.1
June	30	0	0	0	0	0	0	30	30	27	25	0	21.4	5.7	4.2
July	31	0	0	0	0	4	0	31	31	31	31	9	23.4	5.2	4.2
August	31	0	0	0	0	14	5	31	31	31	31	23	24.7	6.9	5.0
September	30	0	0	0	0	0	0	30	30	30	30	0	21.8	6.3	4.2
October	31	0	0	0	0	0	0	31	8	3	2	0	19.5	3.9	2.1
November	30	0	0	0	0	0	0	18	0	0	0	0	14.8	1.6	0.9
December	31	0	6	0	3	0	0	0	0	0	0	0	8.6	3.5	0.8

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	16	0	11	0	0	0	0	0	0	0	7.9	2.5	1.4
February	28	1	17	0	7	0	0	0	0	0	0	0	7.9	3.5	2.3
March	31	0	7	0	0	0	0	0	0	0	0	0	11.3	3.9	2.6
April	30	0	0	0	0	0	0	7	0	0	0	0	13.7	6.2	4.1
May	31	0	0	0	0	0	0	31	8	0	0	0	17.7	6.5	4.9
June	30	0	0	0	0	0	0	30	30	26	24	0	20.9	6.4	4.8
July	31	0	0	0	0	0	0	31	31	31	31	0	22.0	5.4	4.0
August	31	0	0	0	0	5	1	31	31	31	31	16	24.1	5.9	4.7
September	30	0	0	0	0	0	0	30	30	28	27	3	22.9	6.0	4.6
October	31	0	0	0	0	0	0	31	5	0	0	0	17.2	3.9	2.4
November	30	0	0	0	0	0	0	1	0	0	0	0	12.5	2.7	1.5
December	31	0	0	0	0	0	0	0	0	0	0	0	9.5	1.8	0.9

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2012.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	22	0	15	0	0	0	0	0	0	0	7.4	2.6	1.5
February	29	0	21	0	8	0	0	0	0	0	0	0	8.5	3.2	1.8
March	31	0	6	0	0	0	0	0	0	0	0	0	9.9	4.5	2.6
April	30	0	0	0	0	0	0	14	0	0	0	0	17.6	5.7	3.7
May	31	0	0	0	0	0	0	31	22	8	2	0	19.1	5.7	4.2
June	27	0	0	0	0	0	0	27	27	22	18	0	20.2	5.0	3.6
July	31	0	0	0	0	0	0	31	31	31	31	0	22.0	5.4	4.0
August	31	0	0	0	0	5	1	31	31	31	31	16	24.1	5.9	4.7
September	30	0	0	0	0	0	0	30	30	28	27	3	22.9	6.0	4.6
October	31	0	0	0	0	0	0	31	5	0	0	0	17.2	3.9	2.4
November	30	0	0	0	0	0	0	1	0	0	0	0	12.5	2.7	1.5
December	31	0	0	0	0	0	0	0	0	0	0	0	9.5	1.8	0.9

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2013.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	26	0	0	0	0	0	0	26	0	0	0	0	16.4	5.8	4.0
May	31	0	0	0	0	0	0	31	29	10	7	0	20.0	5.6	3.9
June	30	0	0	0	0	0	0	30	30	30	28	0	22.0	4.7	3.3
July	31	0	0	0	0	8	1	31	31	31	31	13	24.0	5.3	4.0
August	31	0	0	0	0	1	0	31	31	31	31	7	23.1	3.9	2.6
September	30	0	0	0	0	0	0	30	23	19	18	0	21.2	2.8	1.8
October	31	0	0	0	0	0	0	31	0	0	0	0	13.7	2.4	1.7
November	30	0	0	0	0	0	0	17	0	0	0	0	13.2	2.2	1.2
December	31	0	6	0	2	0	0	0	0	0	0	0	10.0	2.0	0.8

Monthly water temperature summary Luna Creek (RM 5.2), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	14	0	3	0	0	0	0	5	0	0	0	0	14.9	8.8	6.3
May	31	0	0	0	0	0	0	31	0	0	0	0	17.1	8.8	4.8
June	30	0	0	0	0	0	0	30	1	0	0	0	16.3	4.7	3.5
July	31	0	0	0	0	0	0	31	2	0	0	0	16.6	3.5	2.3
August	31	0	0	0	0	0	0	31	0	0	0	0	16.2	2.1	1.2
September	30	0	0	0	0	0	0	30	0	0	0	0	14.2	2.6	1.8
October	31	0	0	0	0	0	0	5	0	0	0	0	12.7	2.0	1.3
November	30	0	0	0	0	0	0	0	0	0	0	0	10.4	1.9	0.9
December	31	0	18	0	16	0	0	0	0	0	0	0	8.1	3.4	1.0

Monthly water temperature summary Luna Creek (RM 5.2), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	31	2	28	0	0	0	0	0	0	0	6.3	4.5	1.5

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
February	28	1	28	0	28	0	0	0	0	0	0	0	6.5	4.7	2.4
March	31	1	29	0	16	0	0	0	0	0	0	0	10.2	6.2	4.1
April	30	0	6	0	0	0	0	8	0	0	0	0	15.3	8.3	5.8
May	31	0	0	0	0	0	0	28	0	0	0	0	15.7	7.6	4.8
June	30	0	0	0	0	0	0	30	0	0	0	0	14.4	2.9	2.1
July	31	0	0	0	0	0	0	31	2	0	0	0	16.2	2.9	1.9
August	31	0	0	0	0	0	0	31	15	0	0	0	17.2	4.0	1.9
September	6	0	0	0	0	0	0	6	3	0	0	0	17.7	3.6	2.5
November	25	0	0	0	0	0	0	0	0	0	0	0	8.0	1.4	0.9
December	31	2	25	1	24	0	0	0	0	0	0	0	7.2	4.3	0.9

Monthly water temperature summary Luna Creek (RM 5.2), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	31	0	25	0	0	0	0	0	0	0	6.2	2.2	1.3
February	28	0	13	0	6	0	0	0	0	0	0	0	8.2	4.3	2.4
March	31	0	12	0	0	0	0	0	0	0	0	0	10.4	5.4	3.9
April	30	0	6	0	0	0	0	18	0	0	0	0	13.8	6.7	4.9
May	31	0	0	0	0	0	0	30	0	0	0	0	15.0	5.9	3.8
June	30	0	0	0	0	0	0	30	0	0	0	0	15.7	5.0	2.6
July	31	0	0	0	0	0	0	31	0	0	0	0	16.1	2.8	1.9
August	31	0	0	0	0	0	0	31	0	0	0	0	15.6	2.0	1.3
September	30	0	0	0	0	0	0	30	0	0	0	0	14.7	2.1	1.3
October	31	0	0	0	0	0	0	9	0	0	0	0	14.1	2.7	1.6
November	30	0	0	0	0	0	0	0	0	0	0	0	10.6	1.6	1.0
December	31	1	26	0	21	0	0	0	0	0	0	0	6.2	2.6	1.3

Monthly water temperature summary Luna Creek (RM 5.2), 2011.

2011	#days recorded	# 1-day min	# 1-day avg	# 1-Day Max	# 7-Day Avg Daily Max	Monthly 1-day max	Monthly 1-day max range	Monthly avg daily

		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			range
January	31	3	28	0	22	0	0	0	0	0	0	0	7.5	3.0	1.8
February	28	3	26	0	21	0	0	0	0	0	0	0	7.0	3.6	2.5
March	31	0	24	0	7	0	0	0	0	0	0	0	12.9	6.8	4.1
April	30	0	6	0	0	0	0	12	0	0	0	0	14.4	9.5	6.2
May	31	0	0	0	0	0	0	31	0	0	0	0	17.3	9.5	6.3
June	30	0	0	0	0	0	0	30	0	0	0	0	16.7	7.1	4.0
July	31	0	0	0	0	0	0	31	0	0	0	0	15.7	3.1	2.1
August	31	0	0	0	0	0	0	31	0	0	0	0	16.1	2.6	2.0
September	30	0	0	0	0	0	0	30	0	0	0	0	15.8	2.7	2.0
October	31	0	0	0	0	0	0	17	0	0	0	0	13.5	2.3	1.4
November	30	0	0	0	0	0	0	0	0	0	0	0	9.3	2.0	1.3
December	31	0	12	0	4	0	0	0	0	0	0	0	6.9	1.9	0.9

Monthly water temperature summary Luna Creek (RM 5.2), 2012.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	31	0	30	0	0	0	0	0	0	0	5.2	2.5	1.3
February	29	1	29	0	26	0	0	0	0	0	0	0	7.8	3.6	2.5
March	31	0	23	0	7	0	0	0	0	0	0	0	10.9	6.4	3.7
April	30	0	5	0	0	0	0	18	0	0	0	0	18.2	9.1	6.0
May	31	0	0	0	0	0	0	31	0	0	0	0	17.1	8.2	5.3
June	27	0	0	0	0	0	0	27	0	0	0	0	16.4	5.5	3.2
November	25	0	0	0	0	0	0	0	0	0	0	0	11.9	2.5	1.1
December	31	2	19	0	15	0	0	0	0	0	0	0	7.8	2.4	1.4

Monthly water temperature summary Luna Creek (RM 5.2), 2013.

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	11	0	11	0	11	0	0	0	0	0	0	0	4.3	2.4	1.4
April	26	0	1	0	0	0	0	14	0	0	0	0	16.3	9.7	6.3
May	31	0	0	0	0	0	0	31	10	3	0	0	18.4	9.3	6.1

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	30	20	4	2	0	18.9	6.9	4.4
July	31	0	0	0	0	0	0	31	18	9	6	0	19.5	4.9	2.9
August	31	0	0	0	0	0	0	31	0	0	0	0	16.2	2.1	1.5
September	30	0	0	0	0	0	0	30	7	0	0	0	16.8	2.6	1.5
October	31	0	0	0	0	0	0	0	0	0	0	0	11.6	3.5	2.1
November	30	0	8	0	1	0	0	0	0	0	0	0	9.8	2.9	1.3
December	31	0	19	0	14	0	0	0	0	0	0	0	8.2	2.1	1.2

Monthly water temperature summary Newell Spring (Squaw Creek tributary RM 0.2), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	15	31	10	31	0	0	0	0	0	0	0	3.0	1.8	0.7
February	29	0	29	0	29	0	0	0	0	0	0	0	3.3	0.7	0.4
March	31	0	31	0	31	0	0	0	0	0	0	0	4.3	1.8	1.0
April	30	0	30	0	27	0	0	0	0	0	0	0	5.6	2.3	1.6
May	31	0	11	0	0	0	0	0	0	0	0	0	9.4	3.3	2.1
June	30	0	0	0	0	0	0	1	0	0	0	0	12.6	3.4	2.4
July	31	0	0	0	0	0	0	7	0	0	0	0	12.8	3.5	2.1
August	3	0	0	0	0	0	0	0	0	0	0	0	11.1	2.7	2.2

Monthly water temperature summary for Newell Spring (Squaw Creek tributary RM 0.2), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
December	18	0	13	0	11	0	0	0	0	0	0	0	7.8	2.9	1.4

Monthly water temperature summary for Newell Spring (Squaw Creek tributary RM 0.2), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	3	0	1	0	0	0	0	0	0	0	10.0	3.0	1.6
February	28	0	2	0	0	0	0	0	0	0	0	0	12.3	5.8	3.0
March	31	0	2	0	0	0	0	12	0	0	0	0	13.2	6.9	5.0
April	30	0	0	0	0	0	0	23	0	0	0	0	15.8	7.3	4.8
May	31	0	0	0	0	0	0	25	0	0	0	0	17.1	5.7	3.4
June	30	0	0	0	0	0	0	30	9	2	0	0	18.2	4.6	2.5
July	31	0	0	0	0	0	0	31	29	26	26	0	21.3	6.2	4.3
August	31	0	0	0	0	0	0	31	28	23	20	0	21.4	6.3	3.8
September	30	0	0	0	0	0	0	30	21	3	0	0	19.2	5.3	3.3
October	31	0	0	0	0	0	0	13	2	0	0	0	17.6	4.6	3.0
November	30	3	9	1	8	0	0	1	0	0	0	0	13.7	3.5	2.1
December	31	0	5	0	1	0	0	0	0	0	0	0	10.9	3.5	1.4

Monthly water temperature summary for Newell Spring (Squaw Creek tributary RM 0.2), 2011

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	6	0	2	0	0	0	0	0	0	0	11.3	3.4	2.0
February	28	1	7	0	2	0	0	0	0	0	0	0	10.8	4.4	2.9
March	31	0	0	0	0	0	0	3	0	0	0	0	14.0	5.5	3.6
April	30	0	0	0	0	0	0	24	0	0	0	0	15.4	6.7	4.5
May	5	0	0	0	0	0	0	5	0	0	0	0	14.1	6.5	4.4
October	26	0	0	0	0	0	0	18	0	0	0	0	14.3	3.7	2.5
November	30	0	0	0	0	0	0	0	0	0	0	0	10.4	3.5	2.2
December	31	0	23	0	16	0	0	0	0	0	0	0	9.8	2.2	1.4

Monthly water temperature summary for Newell Spring (Squaw Creek tributary RM 0.2), 2012.

2012	#days recorded	# 1-day min	# 1-day avg	# 1-Day Max	# 7-Day Avg Daily Max	Monthly 1-day max	Monthly 1-day max range	Monthly avg daily

		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			range
January	31	0	15	0	11	0	0	0	0	0	0	0	9.0	3.3	1.9
February	29	0	2	0	0	0	0	0	0	0	0	0	11.3	4.2	2.6
March	31	0	1	0	0	0	0	0	0	0	0	0	12.7	6.7	3.9
April	30	0	0	0	0	0	0	27	9	5	4	0	22.5	10.9	6.6
May	31	0	0	0	0	2	0	31	22	13	11	0	23.8	13.0	7.7
June	30	0	0	0	0	2	0	30	26	20	14	0	23.8	10.9	6.1
July	31	0	0	0	0	0	0	31	31	28	27	0	22.0	5.5	3.6
August	31	0	0	0	0	0	0	31	31	23	21	0	21.8	4.5	3.0
September	30	0	0	0	0	0	0	30	16	0	0	0	17.7	4.4	3.1
October	31	0	0	0	0	0	0	14	0	0	0	0	15.2	3.2	1.8
November	30	0	0	0	0	0	0	6	0	0	0	0	14.6	2.9	1.2
December	31	0	0	0	0	0	0	0	0	0	0	0	11.0	2.4	0.9

Monthly water temperature summary for Newell Spring (Squaw Creek tributary RM 0.2), 2013.

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	5	0	0	0	0	0	0	0	0	0	9.8	2.5	1.3
February	28	0	0	0	0	0	0	0	0	0	0	0	10.7	3.6	2.8
March	31	0	0	0	0	0	0	4	0	0	0	0	13.7	4.2	2.6
April	30	0	0	0	0	0	0	20	0	0	0	0	15.2	4.8	3.1
May	31	0	0	0	0	0	0	31	9	4	3	0	19.2	6.3	3.6
June	30	0	0	0	0	0	0	30	15	6	4	0	21.1	4.7	2.8
July	31	0	0	0	0	0	0	31	31	31	29	0	22.4	3.4	2.2
August	31	0	0	0	0	0	0	31	31	31	29	0	20.1	2.4	1.5
September	30	0	0	0	0	0	0	30	19	16	12	0	19.5	1.7	1.0
October	31	0	0	0	0	0	0	2	0	0	0	0	12.6	1.4	0.6
November	30	0	9	0	8	0	0	0	0	0	0	0	10.2	2.3	0.6
December	31	0	20	0	16	0	0	0	0	0	0	0	7.3	2.0	0.8

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily

		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			range
January	31	6	31	5	30	0	0	0	0	0	0	0	5.4	2.9	1.4
February	29	0	24	0	15	0	0	0	0	0	0	0	7.6	3.1	2.2
March	31	0	13	0	0	0	0	0	0	0	0	0	9.3	5.1	3.0
April	30	0	3	0	0	0	0	6	0	0	0	0	15.3	6.8	4.9
May	31	0	0	0	0	0	0	31	18	12	8	0	21.1	7.6	5.0
June	30	0	0	0	0	3	3	30	30	27	23	5	25.3	8.2	6.0
July	21	0	0	0	0	12	3	21	21	21	21	21	25.2	5.3	3.8
August	19	0	0	0	0	15	9	19	19	19	19	19	26.7	6.4	4.6
October	23	0	0	0	0	1	1	15	3	0	0	0	24.6	8.3	2.4
November	30	0	0	0	0	0	0	2	0	0	0	0	13.9	2.9	1.5
December	31	4	16	1	14	0	0	0	0	0	0	0	10.6	2.9	1.6

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	2	26	0	24	0	0	0	0	0	0	0	7.1	3.6	1.3
February	28	0	23	0	13	0	0	0	0	0	0	0	7.4	3.3	1.9
March	31	0	16	0	6	0	0	0	0	0	0	0	9.9	4.3	2.9
April	30	0	1	0	0	0	0	12	0	0	0	0	16.3	6.5	4.5
May	31	0	0	0	0	1	0	31	17	15	13	1	23.0	7.5	5.9
June	30	0	0	0	0	2	0	30	30	30	30	13	23.1	7.0	5.2
July	31	0	0	0	0	25	21	31	31	31	31	31	29.5	6.7	5.0
August	31	0	0	0	0	30	27	31	31	31	31	31	31.4	13.6	8.2
September	30	0	0	0	0	12	9	30	30	29	28	19	31.9	15.4	7.7
October	31	0	0	0	0	0	0	25	1	0	0	0	16.6	4.2	2.1
November	30	0	0	0	0	0	0	0	0	0	0	0	12.3	2.1	1.4
December	31	6	24	3	20	0	0	0	0	0	0	0	8.4	3.3	1.2

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	11	0	5	0	0	0	0	0	0	0	7.2	2.0	1.0
February	28	0	5	0	0	0	0	0	0	0	0	0	8.8	3.6	2.0
March	31	0	2	0	0	0	0	0	0	0	0	0	12.1	5.5	3.8
April	30	0	0	0	0	0	0	18	0	0	0	0	15.1	6.1	4.5
May	31	0	0	0	0	0	0	31	15	4	3	0	18.9	7.3	4.9
June	30	0	0	0	0	2	0	30	30	26	23	3	23.5	6.8	5.1
July	31	0	0	0	0	17	11	31	31	31	31	26	24.9	6.9	4.7
August	31	0	0	0	0	20	14	31	31	31	31	26	25.8	6.9	4.8
September	30	0	0	0	0	0	0	30	30	30	30	0	21.5	5.8	3.4
October	31	0	0	0	0	0	0	31	8	3	2	0	19.5	3.0	1.6
November	30	0	6	0	3	0	0	6	0	0	0	0	13.9	2.3	1.5
December	31	0	11	0	9	0	0	0	0	0	0	0	7.2	2.8	0.9

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	16	0	14	0	0	0	0	0	0	0	7.5	1.9	1.2
February	28	1	20	0	8	0	0	0	0	0	0	0	7.6	3.5	2.2
March	31	0	12	0	0	0	0	0	0	0	0	0	10.8	3.7	2.5
April	30	0	0	0	0	0	0	0	0	0	0	0	12.3	5.7	3.5
May	31	0	0	0	0	0	0	31	0	0	0	0	16.6	5.1	3.3
June	30	0	0	0	0	0	0	30	30	25	23	0	21.5	6.7	5.2
July	31	0	0	0	0	5	0	31	31	31	31	13	24.0	6.8	4.7
August	31	0	0	0	0	26	13	31	31	31	31	31	27.2	7.6	5.1
September	30	0	0	0	0	7	0	30	30	29	28	13	24.0	9.6	4.9
October	31	0	0	0	0	0	0	26	5	0	0	0	17.3	3.4	1.7
November	30	0	0	0	0	0	0	0	0	0	0	0	11.1	2.3	1.4

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	16	0	14	0	0	0	0	0	0	0	7.5	1.9	1.2
February	28	1	20	0	8	0	0	0	0	0	0	0	7.6	3.5	2.2
March	31	0	12	0	0	0	0	0	0	0	0	0	10.8	3.7	2.5
April	30	0	0	0	0	0	0	0	0	0	0	0	12.3	5.7	3.5
May	31	0	0	0	0	0	0	31	0	0	0	0	16.6	5.1	3.3
June	30	0	0	0	0	0	0	30	30	25	23	0	21.5	6.7	5.2
July	31	0	0	0	0	5	0	31	31	31	31	13	24.0	6.8	4.7
August	31	0	0	0	0	26	13	31	31	31	31	31	27.2	7.6	5.1
September	30	0	0	0	0	7	0	30	30	29	28	13	24.0	9.6	4.9
October	31	0	0	0	0	0	0	26	5	0	0	0	17.3	3.4	1.7
November	30	0	0	0	0	0	0	0	0	0	0	0	11.1	2.3	1.4
December	31	0	19	0	11	0	0	0	0	0	0	0	7.9	2.0	1.2

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2012.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	26	0	22	0	0	0	0	0	0	0	6.7	2.8	1.6
February	29	0	25	0	15	0	0	0	0	0	0	0	8.2	3.6	1.8
March	31	0	12	0	1	0	0	0	0	0	0	0	9.5	4.7	2.7
April	30	0	0	0	0	0	0	13	0	0	0	0	17.4	5.7	3.8
May	31	0	0	0	0	0	0	31	22	9	5	0	19.8	6.6	4.6
June	27	0	0	0	0	0	0	27	27	23	20	0	21.6	6.2	4.3

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2013.

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	26	0	0	0	0	0	0	19	0	0	0	0	16.7	6.6	4.4

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
May	31	0	0	0	0	0	0	31	29	13	11	0	21.2	6.7	4.7
June	30	0	0	0	0	2	1	30	30	30	30	3	24.5	5.9	3.9
July	31	0	0	0	0	26	19	31	31	31	31	31	27.0	6.0	4.1
August	10	0	0	0	0	9	9	10	10	10	10	10	28.2	7.5	5.7
September	24	0	0	0	0	11	10	24	22	18	17	13	29.9	11.4	5.8
October	31	0	0	0	0	0	0	26	0	0	0	0	15.9	4.2	2.3
November	30	0	7	0	2	0	0	0	0	0	0	0	11.9	3.4	1.2
December	31	2	21	2	20	0	0	0	0	0	0	0	8.9	3.0	1.4

Monthly water temperature summary for Squaw Creek (RM 1), 2008.

2008	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
April	14	0	3	0	0	0	0	0	0	0	0	0	12.9	6.0	4.6
May	31	0	0	0	0	0	0	21	0	0	0	0	16.4	5.9	3.5
June	30	0	0	0	0	0	0	30	6	3	1	0	19.2	4.3	3.2
July	31	0	0	0	0	0	0	31	31	31	31	0	20.3	5.6	4.2
August	31	0	0	0	0	0	0	31	31	24	16	0	20.3	4.4	2.8
September	2	0	0	0	0	0	0	2	2	0	0	0	16.0	3.5	3.4
October	9	0	0	0	0	0	0	0	0	0	0	0	9.6	2.4	1.8
November	30	0	0	0	0	0	0	0	0	0	0	0	11.3	2.6	1.3
December	31	7	19	1	18	0	0	0	0	0	0	0	8.1	2.3	1.3

Monthly water temperature summary for Squaw Creek (RM 1), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	2	31	2	30	0	0	0	0	0	0	0	5.5	3.6	1.3
February	28	0	28	0	28	0	0	0	0	0	0	0	5.1	3.5	1.6
March	31	0	29	0	18	0	0	0	0	0	0	0	8.1	4.5	2.9
April	30	0	5	0	1	0	0	3	0	0	0	0	13.9	6.2	4.3

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
May	31	0	0	0	0	0	0	18	3	0	0	0	16.9	5.2	3.8
June	30	0	0	0	0	0	0	30	26	3	1	0	18.1	4.8	3.3
July	31	0	0	0	0	0	0	31	31	31	31	1	21.1	6.2	4.3
August	11	0	0	0	0	7	6	11	11	11	11	11	27.1	9.9	5.3
September	30	0	0	0	0	3	1	30	30	30	30	3	24.9	4.6	2.9
October	31	0	0	0	0	0	0	31	31	31	20	0	20.8	6.2	2.3
November	30	0	0	0	0	0	0	6	4	3	2	0	19.8	11.7	1.8
December	31	6	30	4	29	0	0	0	0	0	0	0	6.6	2.3	1.1

Monthly water temperature summary for Squaw Creek (RM 1), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	31	0	28	0	0	0	0	0	0	0	5.6	1.8	1.0
February	28	0	19	0	7	0	0	0	0	0	0	0	7.1	3.3	1.8
March	31	0	15	0	0	0	0	0	0	0	0	0	9.1	4.3	3.2
April	30	0	4	0	0	0	0	0	0	0	0	0	12.0	5.1	3.6
May	31	0	0	0	0	0	0	11	0	0	0	0	14.0	4.3	2.8
June	30	0	0	0	0	0	0	30	5	0	0	0	17.3	3.7	2.7
July	31	0	0	0	0	0	0	31	27	24	23	0	20.4	6.4	4.4
August	31	0	0	0	0	5	2	31	31	31	28	6	24.9	15.0	6.3
September	30	0	0	0	0	2	1	30	30	30	30	0	24.7	11.3	3.0
October	31	0	0	0	0	3	0	31	31	31	31	4	23.3	9.2	3.6
November	30	0	8	0	8	3	0	11	8	7	7	2	23.2	15.1	2.4
December	31	1	30	1	23	0	0	0	0	0	0	0	5.7	3.9	1.1

Monthly water temperature summary for Squaw Creek (RM 1), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	7	31	4	28	0	0	0	0	0	0	0	6.0	2.8	1.5

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
February	28	3	28	1	23	0	0	0	0	0	0	0	5.9	3.0	2.0
March	31	0	28	0	19	0	0	0	0	0	0	0	9.7	4.6	2.7
April	30	0	7	0	0	0	0	0	0	0	0	0	11.0	6.3	4.2
May	31	0	0	0	0	0	0	11	0	0	0	0	13.8	6.1	3.9
June	30	0	0	0	0	0	0	30	0	0	0	0	15.9	4.5	3.0
July	31	0	0	0	0	0	0	31	29	4	2	0	18.7	4.6	3.4
August	31	0	0	0	0	0	0	31	31	24	17	0	19.1	4.4	3.3
September	30	0	0	0	0	0	0	30	1	0	0	0	16.1	4.0	2.9
October	31	0	0	0	0	0	0	6	0	0	0	0	13.0	2.3	1.4
November	30	0	0	0	0	0	0	0	0	0	0	0	8.3	2.4	1.4
December	31	0	30	0	26	0	0	0	0	0	0	0	6.1	1.8	1.0

Monthly water temperature summary for Squaw Creek 1 (RM 1), 2012.

2012	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	2	31	0	30	0	0	0	0	0	0	0	5.1	2.7	1.4
February	29	0	29	0	27	0	0	0	0	0	0	0	6.6	3.2	1.9
March	31	0	26	0	11	0	0	0	0	0	0	0	8.2	4.7	2.8
April	30	0	6	0	0	0	0	7	0	0	0	0	14.3	5.4	3.7
May	31	0	0	0	0	0	0	23	0	0	0	0	14.6	6.6	3.1
June	30	0	0	0	0	0	0	30	0	0	0	0	16.0	3.5	2.4
July	31	0	0	0	0	0	0	31	28	24	22	0	18.9	3.8	3.1
August	31	0	0	0	0	0	0	31	31	21	16	0	19.1	4.9	2.4
September	30	0	0	0	0	5	4	30	30	23	20	7	32.4	17.2	5.5
October	5	0	0	0	0	0	0	5	5	5	5	0	22.5	4.0	2.8
November	25	0	0	0	0	0	0	5	2	1	1	0	19.7	12.4	1.5
December	31	0	18	0	15	0	0	0	0	0	0	0	7.7	2.4	1.1

Monthly water temperature summary for Squaw Creek 1 (RM 1), 2013.

2013	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	5	31	1	31	0	0	0	0	0	0	0	4.6	2.9	1.0
February	28	0	28	0	27	0	0	0	0	0	0	0	6.1	2.9	2.1
March	31	0	17	0	9	0	0	0	0	0	0	0	10.7	4.7	2.9
April	30	0	0	0	0	0	0	0	0	0	0	0	12.2	4.9	3.2
May	31	0	0	0	0	0	0	23	0	0	0	0	15.2	4.3	2.7
June	30	0	0	0	0	0	0	30	3	1	1	0	18.4	3.8	2.6
July	31	0	0	0	0	0	0	31	31	24	18	0	19.4	3.6	2.5
August	31	0	0	0	0	2	0	31	31	31	29	5	23.5	10.3	4.6
September	30	0	1	0	0	3	1	30	21	19	18	0	25.0	13.9	5.3
October	31	0	0	0	0	0	0	1	0	0	0	0	12.0	1.6	1.0
November	30	0	9	0	9	0	0	0	0	0	0	0	8.8	2.3	0.9
December	31	6	29	2	28	0	0	0	0	0	0	0	6.6	2.0	1.2

Monthly water temperature summary for Squaw Creek Confluence (RM 0), 2009.

2009	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
December	21	0	13	0	10	0	0	0	0	0	0	0	7.2	2.5	1.1

Monthly water temperature summary for Squaw Creek Confluence (RM 0), 2010.

2010	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	5	0	3	0	0	0	0	0	0	0	7.3	1.8	1.0

Monthly water temperature summary for Squaw Creek Confluence (RM 0), 2011.

2011	#days recorded	# 1-day min		# 1-day avg		# 1-Day Max		# 7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max range	Monthly avg daily range
		< 0.5	< 4.4	< 0.5	< 4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	9	20	5	15	0	0	0	0	0	0	0	10.0	5.6	2.1
February	28	1	20	0	9	0	0	0	0	0	0	0	7.6	3.4	2.3
March	31	0	12	0	0	0	0	0	0	0	0	0	11.3	4.2	2.6
April	30	0	0	0	0	0	0	1	0	0	0	0	12.7	6.2	4.0
May	31	0	0	0	0	0	0	31	0	0	0	0	16.6	6.4	4.7
June	30	0	0	0	0	0	0	30	29	21	13	0	19.9	6.4	4.8
July	31	0	0	0	0	2	0	31	31	31	31	3	23.4	7.3	4.8
August	12	0	0	0	0	11	8	12	12	12	12	12	26.3	11.5	9.4

NOTE: All Temperatures and Ranges in degrees C

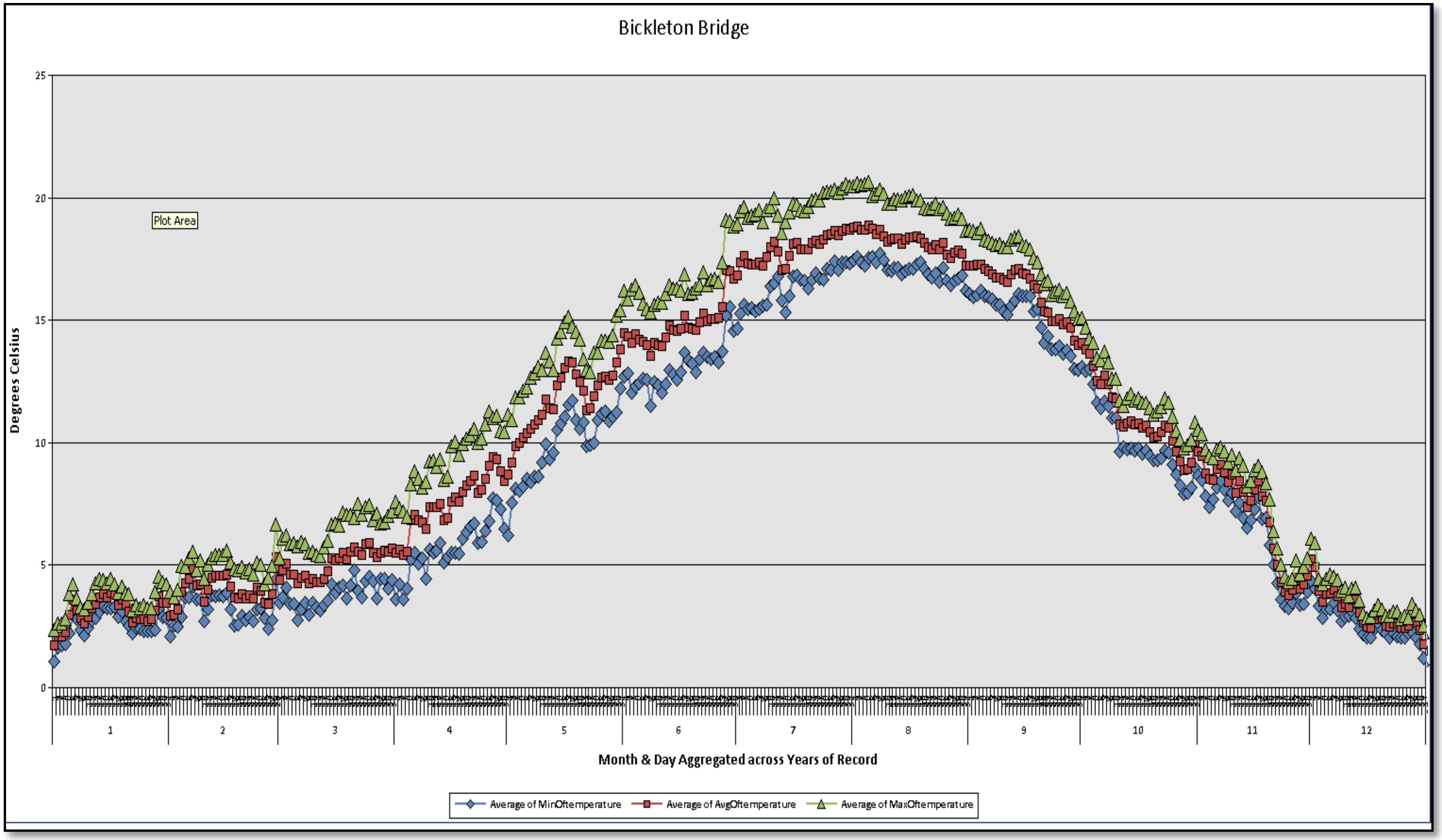

Figure C-i. Average minimum and average maximum water temperature measured at Bickleton Bridge (RM 13), 2008–2013.

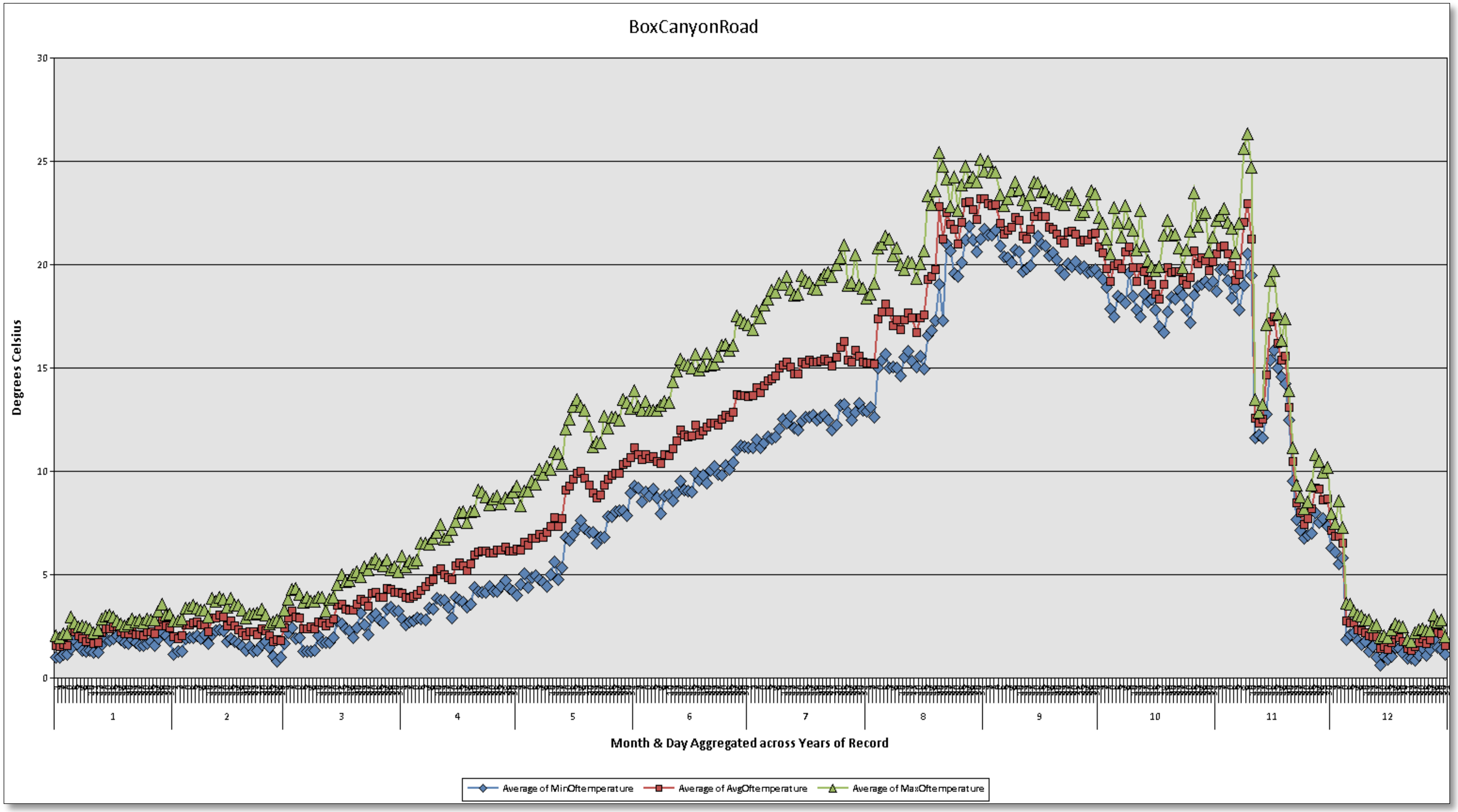

Figure C-ii. Average minimum and average maximum water temperature measured at Box Canyon Rd. (RM 21), 2008–2012.

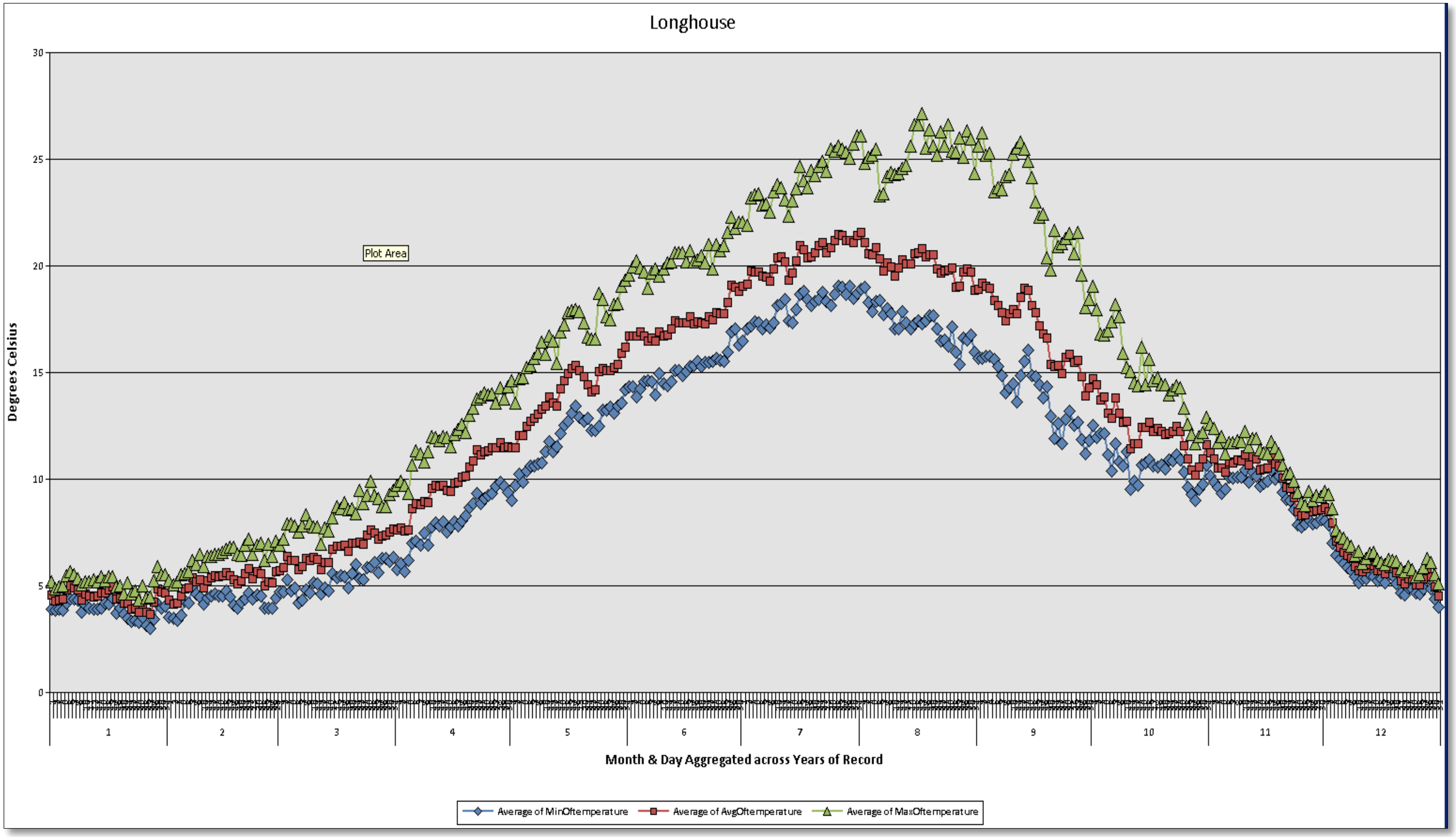

Figure C-iii. Average minimum and average maximum water temperature measured at the Longhouse (RM 2.2), 2008–2013.

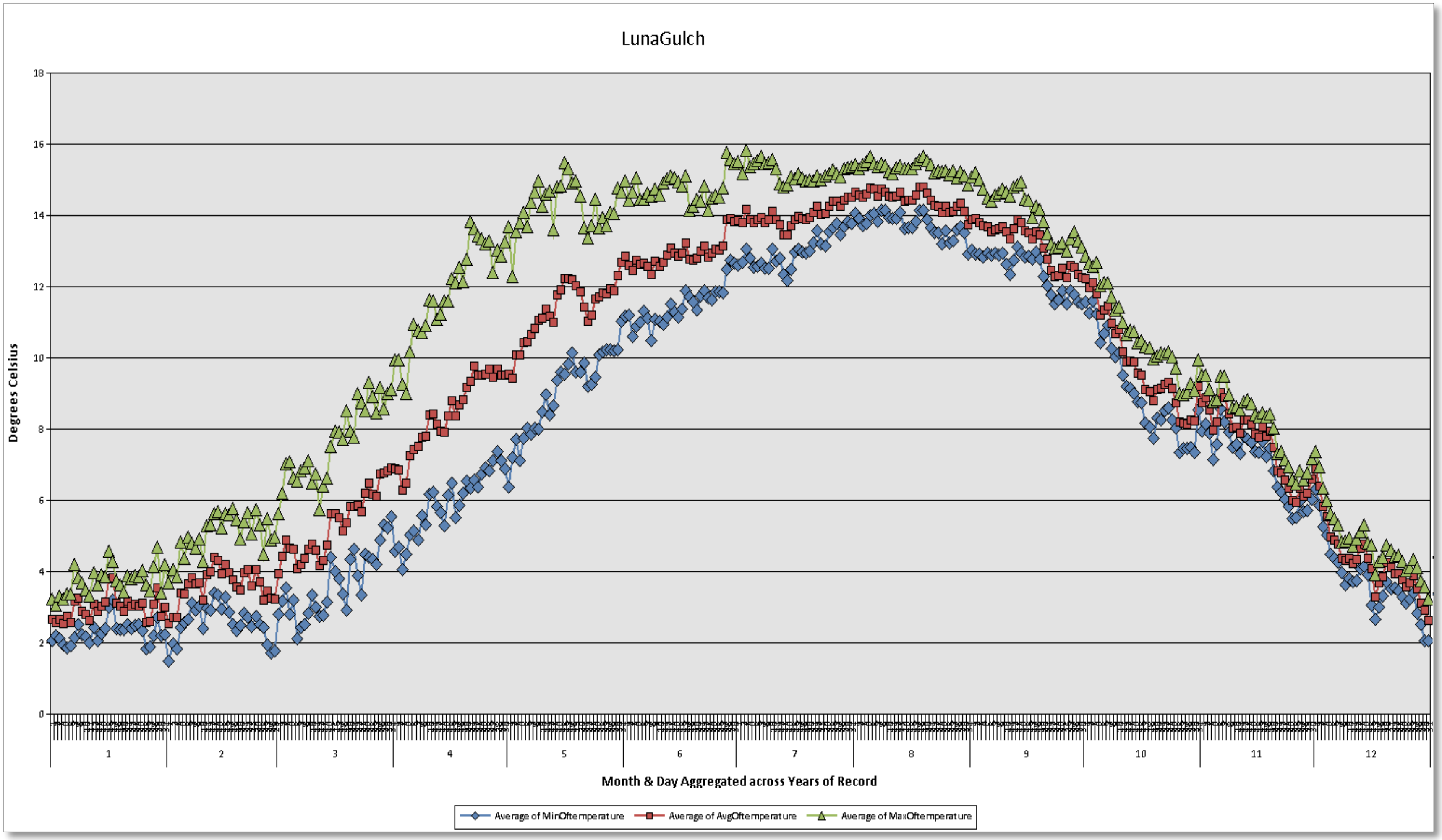

Figure C-iv. Average minimum and average maximum water temperature measured at Luna Creek (RM 5.2), 2008–2013.

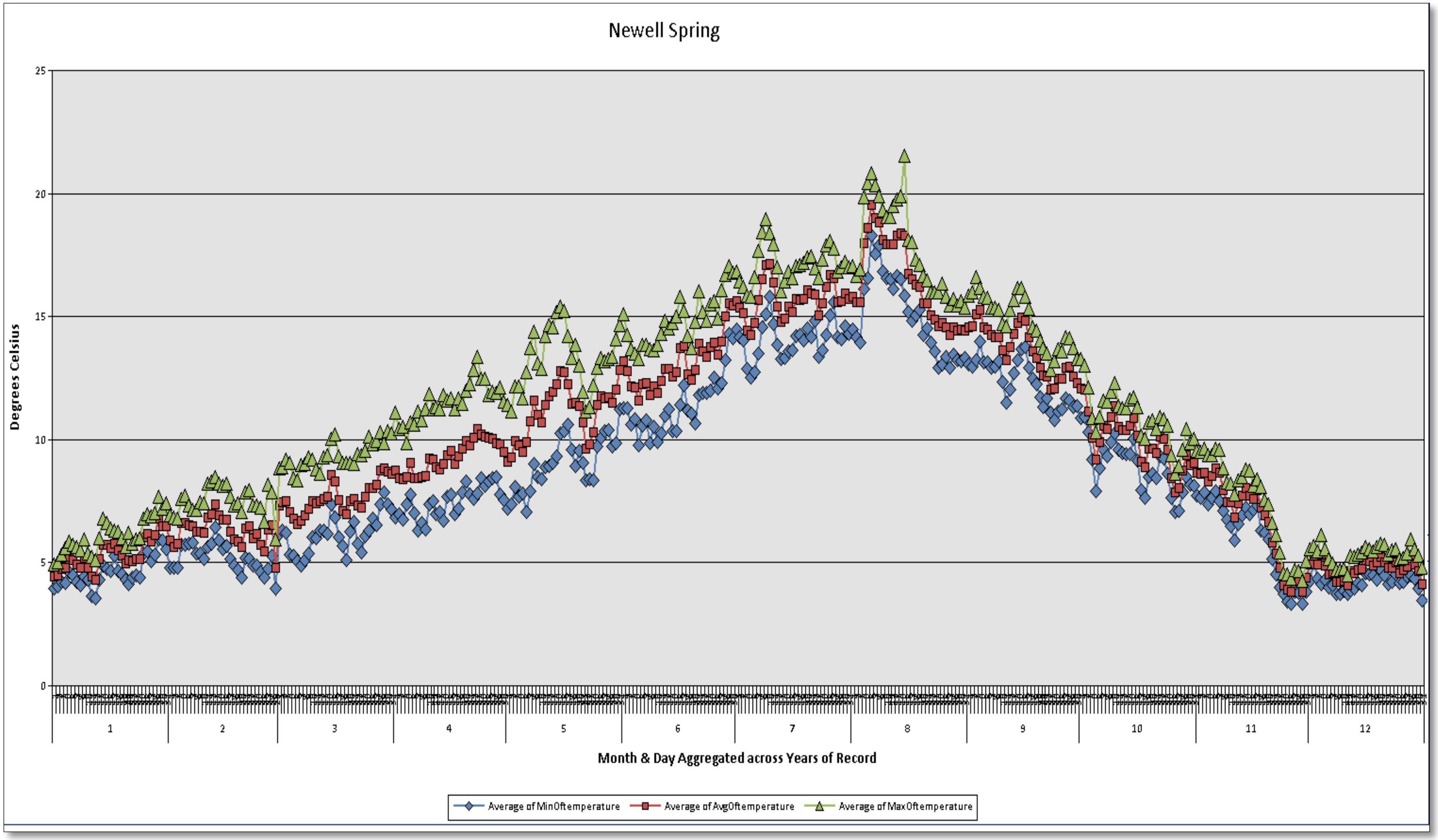

Figure C-v. Average minimum and average maximum water temperature measured at Newell Spring (RM 0.2), 2008–2013.

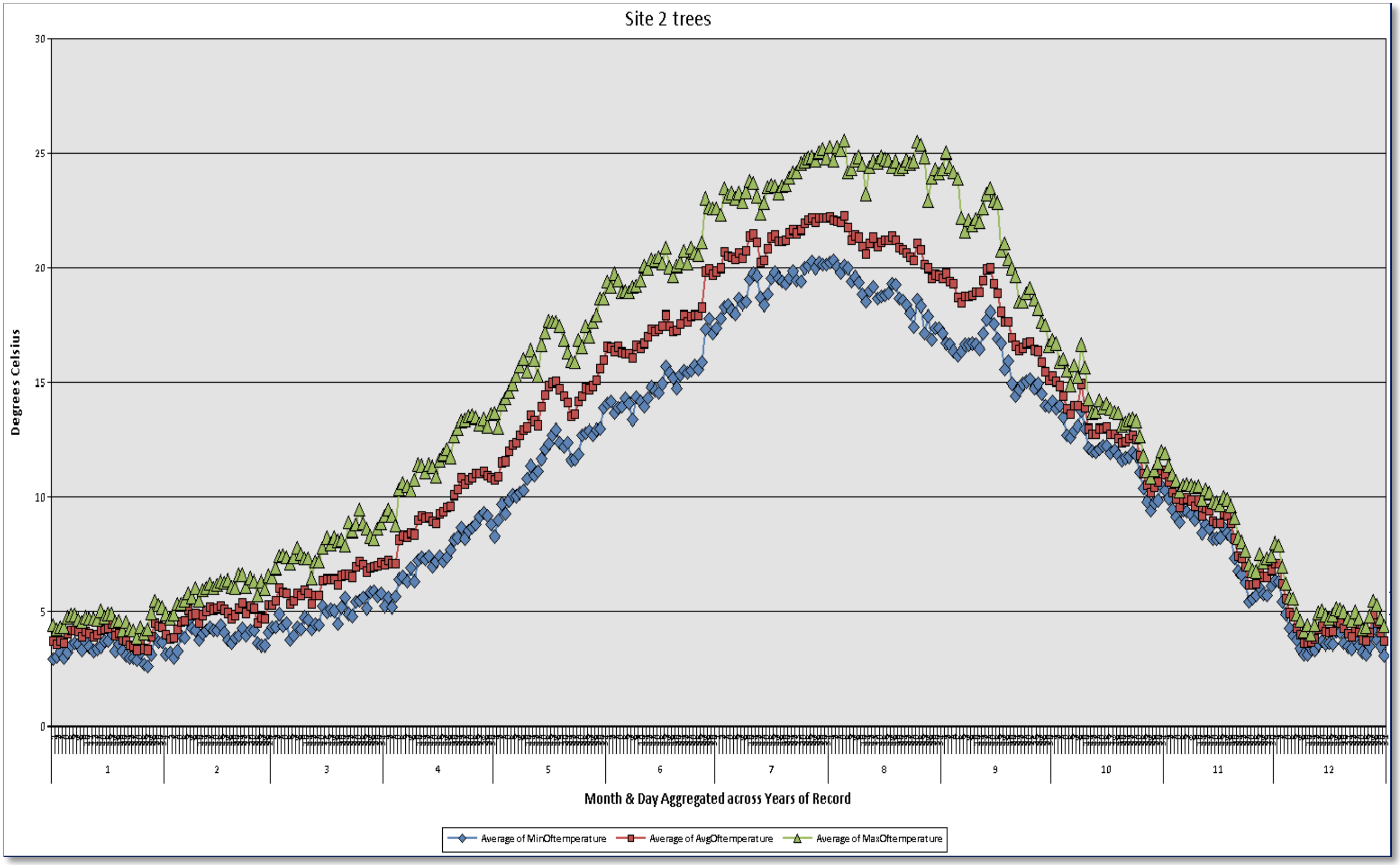

Figure C-vi. Average minimum and average maximum water temperature measured at Site 2 Trees (RM 5), 2008–2013.

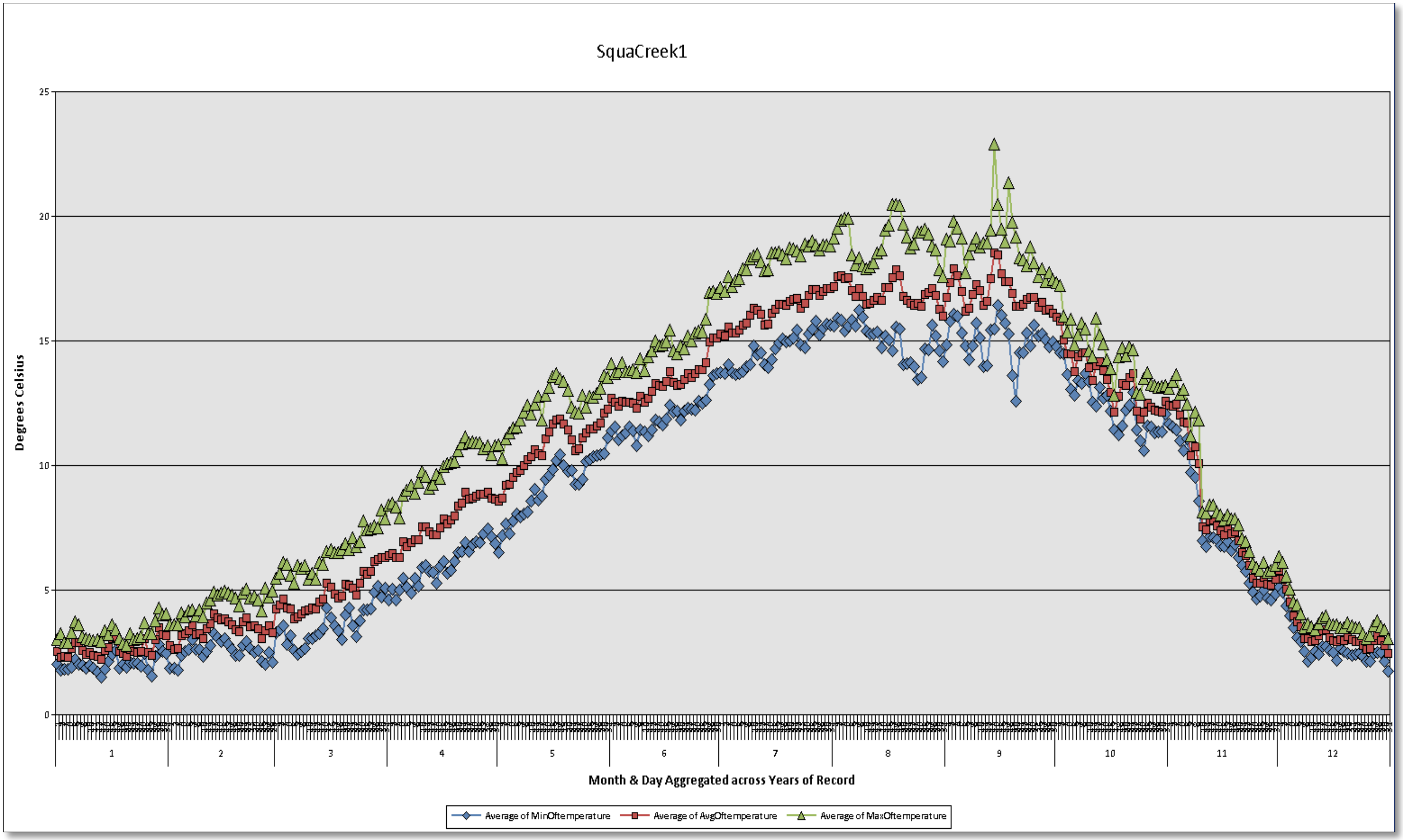

Figure C-vii. Average minimum and average maximum water temperature measured at Squaw Creek 1 (RM 1), 2008–2013.

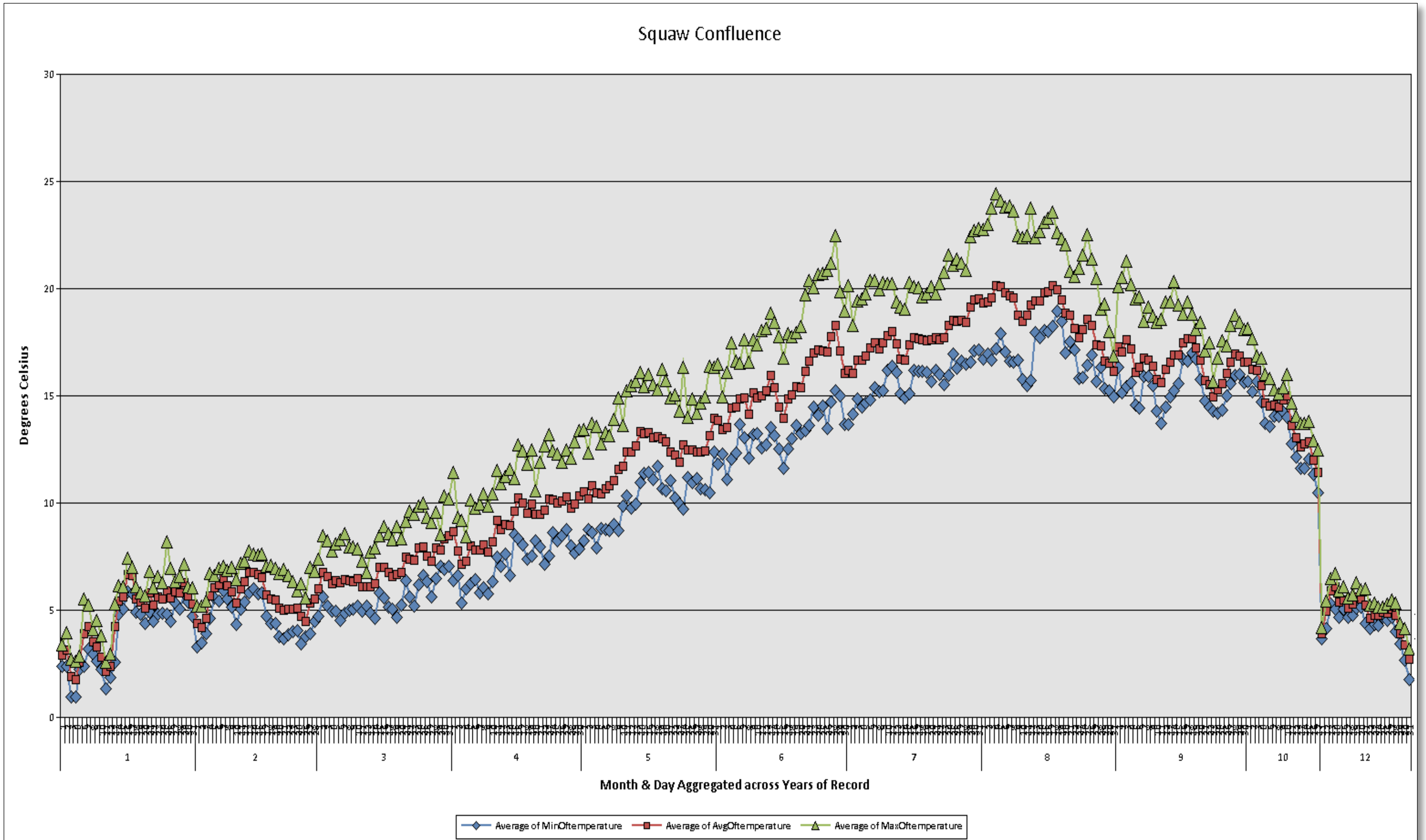

Figure C-viii. Average minimum and average maximum water temperature measured at Squaw Creek confluence (RM 0), 2009–2011.

Appendix D. Raw genetic assignment results for Rock Creek steelhead.

Table D-i. Raw assignment results based on “unknown” mixture analysis in GENECLASSv2. The top five ranked assignments (descending probability) are shown for each RSC individual, grouped by river reach. All Rock Creek, Ekone Falls and Quartz Creek assignments for rank 1&2 are highlighted in gray, and corresponding probability values (Prob.) exceeding 75% are bolded and underlined.

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2008_28_FALL	1-9	Ekone	48.2	ROCK	21.4	UCOL	19.1	LR	5.6	GRIM	4.1
Rock_2011_RC196_FALL	1-9	GRIM	55.2	LR	17.4	UPSal	17.1	UCOL	5.9	rock	4.2
Omy_RockCr12-RC0259	1-9	GRIM	63.8	UCOL	24.7	UPSal	5.2	rock	2.9	LR	2.7
Omy_RockCr12-RC0261	1-9	GRIM	72.1	UCOL	9.6	LR	8.7	rock	6.0	UPSal	3.2
Rock_2008_4_FALL	1-9	GRIM	76.5	ROCK	14.7	LR	7.0	UCOL	0.7	MC	0.5
Rock_2011_RC194_FALL	1-9	LR	50.6	ROCK	24.7	MC	20.0	UCOL	3.1	UPSal	1.1
Rock_2008_22_FALL	1-9	LR	56.7	ROCK	27.6	GRIM	8.2	MC	5.9	UPSal	1.0
Rock_2008_19_FALL	1-9	MC	39.7	ROCK	31.1	LR	21.3	UCOL	5.8	GRIM	1.4
Rock_2008_1_FALL	1-9	MC	47.8	LR	20.9	UCOL	13.4	GRIM	13.4	rock	4.1
Rock_2011_RC05_SPRING	1-9	MCSC	74.9	ROCK	18.6	GRIM	2.9	LR	2.0	UPSal	1.5
Rock_2008_6_FALL	1-9	MCSC	81.7	LR	16.0	rock	2.3	GRIM	0.0	UCOL	0.0
Omy_RockCr12-RC0262	1-9	MCSC	85.0	LR	9.0	rock	2.9	UCOL	2.8	GRIM	0.2
Rock_2011_RC190_FALL	1-9	MCSC	85.5	ROCK	13.3	LR	1.0	GRIM	0.0	MC	0.0
Rock_2008_31_FALL	1-9	MCSC	88.5	ROCK	10.2	LR	1.0	GRIM	0.2	UPSal	0.0
Rock_2011_RC186_FALL	1-9	MCSC	93.2	LR	4.1	rock	1.3	UPSal	0.6	UCOL	0.4
Rock_2008_5_FALL	1-9	MCSC	96.3	LR	2.0	rock	1.5	UPSal	0.2	GRIM	0.0
Omy_RockCr12-RC0241	1-9	MCSC	98.5	ROCK	1.0	LR	0.5	UCOL	0.0	GRIM	0.0
Rock_2011_RC03_SPRING	1-9	ROCK	34.3	UPSal	30.6	LR	17.6	UCOL	10.9	GRIM	4.4
Rock_2008_23_FALL	1-9	ROCK	37.5	MC	29.0	GRIM	12.9	LR	11.5	UCOL	8.1
Rock_2008_27_FALL	1-9	ROCK	38.3	GRIM	28.0	LR	26.1	MC	6.1	UCOL	0.8
Rock_2008_34_FALL	1-9	ROCK	42.6	LR	42.4	GRIM	11.4	MCSC	3.1	MC	0.5
Rock_2008_9_FALL	1-9	ROCK	43.0	MC	35.8	GRIM	11.3	LR	8.4	UCOL	1.5
Rock_2008_12_FALL	1-9	ROCK	56.0	LR	33.5	GRIM	7.3	MC	1.5	UPSal	1.0
Rock_2008_13_FALL	1-9	ROCK	56.3	UCOL	23.3	MC	15.4	LR	4.0	UPSal	1.0
Rock_2011_RC19_SPRING	1-9	ROCK	61.6	LR	15.3	UCOL	14.9	MC	3.9	GRIM	3.7
Rock_2008_16_FALL	1-9	ROCK	62.1	UCOL	15.4	LR	13.3	MC	7.2	UPSal	1.3
Rock_2011_RC16_SPRING	1-9	ROCK	65.0	UCOL	17.5	MC	16.5	LR	0.9	GRIM	0.1

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2011_RC06_SPRING	1-9	ROCK	66.4	MC	20.7	UCOL	5.3	LR	4.4	GRIM	2.6
Omy_RockCr12-RC0414	1-9	ROCK	67.2	LR	25.7	GRIM	2.4	MC	2.1	UCOL	1.8
Rock_2008_21_FALL	1-9	ROCK	70.6	MC	16.6	LR	6.7	GRIM	4.2	UCOL	1.3
Rock_2008_18_FALL	1-9	ROCK	71.1	MC	25.2	LR	1.9	GRIM	1.1	UCOL	0.7
Rock_2008_17_FALL	1-9	ROCK	71.7	LR	9.7	GRIM	9.0	UPSal	4.8	UCOL	3.4
Rock_2011_RC197_FALL	1-9	ROCK	72.1	MSSFS	19.5	GRIM	3.9	LR	3.6	MC	0.4
Rock_2011_RC04_SPRING	1-9	ROCK	73.3	LR	9.6	GRIM	9.4	UPSal	4.8	MCSC	2.7
Rock_2008_20_FALL	1-9	ROCK	73.5	GRIM	12.8	LR	9.4	UCOL	2.3	MC	1.2
Rock_2008_15_FALL	1-9	ROCK	**76.9**	MC	12.6	LR	5.4	GRIM	3.0	UCOL	1.2
Rock_2008_7_FALL	1-9	ROCK	**77.6**	LR	12.5	GRIM	8.6	MCSC	0.7	MC	0.5
Rock_2008_14_FALL	1-9	ROCK	**77.8**	MC	13.0	UPSal	4.6	UCOL	3.1	LR	1.3
Rock_2008_32_FALL	1-9	ROCK	**77.9**	MC	14.1	LR	7.4	UCOL	0.5	GRIM	0.1
Rock_2011_RC198_FALL	1-9	ROCK	**81.6**	LR	9.7	MCSC	4.1	GRIM	2.1	UPSal	1.6
Omy_RockCr12-RC0243	1-9	ROCK	**82.2**	LR	7.0	MC	6.2	UPSal	2.7	UCOL	1.8
Rock_2008_11_FALL	1-9	ROCK	**82.7**	LR	14.1	GRIM	2.4	UCOL	0.5	MC	0.2
Omy_RockCr12-RC0413	1-9	ROCK	**86.0**	LR	11.8	MC	1.0	UPSal	0.8	GRIM	0.2
Rock_2008_33_FALL	1-9	ROCK	**86.3**	LR	6.4	GRIM	2.9	UPSal	1.6	UCOL	1.5
Rock_2011_RC195_FALL	1-9	ROCK	**88.8**	LR	4.4	GRIM	3.2	MCSC	2.6	MC	0.6
Rock_2011_RC192_FALL	1-9	ROCK	**89.6**	LR	4.3	MCSC	4.2	GRIM	1.2	UPSal	0.7
Rock_2008_3_FALL	1-9	ROCK	**90.1**	LR	6.2	UPSal	1.7	GRIM	1.2	MCSC	0.4
Rock_2008_29_FALL	1-9	ROCK	**90.9**	LR	3.2	MC	3.0	GRIM	2.6	UCOL	0.1
Rock_2008_24_FALL	1-9	ROCK	**91.9**	LR	7.9	GRIM	0.1	MCSC	0.0	UCOL	0.0
Rock_2008_10_FALL	1-9	ROCK	**92.9**	MC	6.6	LR	0.4	UCOL	0.1	GRIM	0.0
Rock_2011_RC02_SPRING	1-9	ROCK	**94.0**	LR	3.7	GRIM	1.2	UPSal	0.9	MCSC	0.1
Rock_2011_RC01_SPRING	1-9	ROCK	**94.0**	LR	4.5	GRIM	1.2	MCSC	0.2	MC	0.0
Rock_2011_RC188_FALL	1-9	ROCK	**94.1**	LR	2.8	MSSFS	1.5	MC	0.8	GRIM	0.7
Omy_RockCr12-RC0257	1-9	ROCK	**95.6**	UCOL	1.5	LR	1.3	GRIM	0.8	MC	0.4
Rock_2008_8_FALL	1-9	ROCK	**96.8**	MC	2.6	UPSal	0.5	UCOL	0.1	GRIM	0.0
Rock_2008_26_FALL	1-9	ROCK	**98.6**	MC	0.6	UCOL	0.4	UPSal	0.3	LR	0.1
Rock_2008_30_FALL	1-9	UCOL	72.8	ROCK	11.8	Ekone	9.4	LR	5.0	GRIM	0.5
Rock_2011_RC187_FALL	1-9	UPSal	34.7	ROCK	30.6	UCOL	14.3	LR	11.7	MC	6.9
Rock_2011_RC200_FALL	1-9	UPSal	34.7	ROCK	21.0	LR	20.6	MC	14.0	GRIM	7.2
Rock_2011_RC199_FALL	1-9	UPSal	44.9	ROCK	23.3	GRIM	15.4	LR	13.1	UCOL	2.1
Omy_RockCr12-RC0263	1-9	UPSal	45.6	LR	33.4	UCOL	8.2	rock	6.8	GRIM	3.1
Rock_2011_RC191_FALL	1-9	UPSal	56.7	UCOL	23.3	rock	12.3	LR	5.0	GRIM	2.4
Rock_2008_25_FALL	1-9	UPSal	84.4	ROCK	5.8	LR	4.5	GRIM	3.8	MC	1.2

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Omy_RockCr12-RC0258	1-9	UPSal	94.8	ROCK	2.9	MC	1.7	LR	0.5	UCOL	0.1
Omy_RockCr12-RC0412	1-9	UPSal	95.0	GRIM	3.4	LR	1.0	rock	0.2	MC	0.1
Rock_2009_1280_34_FALL	15-19	GRIM	29.3	UPSal	24.3	rock	15.0	MC	11.1	LR	10.5
Rock_2010_1281_010_SPRING	15-19	GRIM	42.8	LR	36.4	rock	6.2	MC	4.1	MSSFS	3.7
Omy_RockCr12-RC0393	15-19	GRIM	46.7	LR	35.7	MC	9.3	rock	7.3	UCOL	1.0
Omy_RockCr12-RC0290	15-19	GRIM	48.6	ROCK	29.2	LR	16.1	UCOL	4.4	MC	1.5
Rock_2011_RC85_SPRING	15-19	GRIM	54.2	LR	27.1	MC	12.1	rock	3.4	UCOL	1.5
Rock_2011_RC105_SPRING	15-19	GRIM	54.5	MC	19.2	rock	13.9	LR	8.2	UCOL	2.5
Rock_2011_RC95_SPRING	15-19	GRIM	55.0	ROCK	25.1	LR	17.8	UPSal	1.5	MSSFS	0.3
Rock_2011_RC108_SPRING	15-19	GRIM	65.3	LR	19.5	MC	5.8	UPSal	4.5	rock	3.9
Omy_RockCr12-RC0279	15-19	GRIM	66.4	LR	27.2	rock	2.7	MSSFS	1.1	UCOL	1.1
Rock_2011_RC89_SPRING	15-19	GRIM	71.2	LR	17.3	rock	5.8	UCOL	2.2	UPSal	2.1
Omy_RockCr12-RC0283	15-19	GRIM	79.7	MC	11.4	rock	4.1	LR	2.9	UPSal	1.2
Rock_2009_1280_48_FALL	15-19	LR	31.3	ROCK	29.2	UCOL	18.2	GRIM	11.9	UPSal	6.3
Rock_2009_1280_37_FALL	15-19	LR	44.0	ROCK	35.8	GRIM	8.9	UCOL	6.6	MC	4.0
Rock_2011_RC75_SPRING	15-19	LR	54.5	ROCK	32.9	MC	8.2	UPSal	2.6	GRIM	1.1
Rock_2011_RC98_SPRING	15-19	LR	54.5	MC	24.7	rock	13.1	UPSal	5.1	UCOL	1.7
Omy_RockCr12-RC0282	15-19	LR	57.3	ROCK	30.8	UPSal	10.6	MC	1.1	GRIM	0.1
Rock_2011_RC139_FALL	15-19	LR	67.1	MC	25.5	rock	5.9	GRIM	0.9	UCOL	0.6
Rock_2010_1281_001_SPRING	15-19	LR	72.0	GRIM	13.2	rock	11.9	MC	1.1	UCOL	0.9
Rock_2009_1280_46_FALL	15-19	LR	75.9	GRIM	19.0	MCSC	2.2	UCOL	1.4	rock	1.3
Rock_2009_1280_40_FALL	15-19	LR	77.2	ROCK	12.3	GRIM	6.5	UPSal	2.3	UCOL	0.9
Rock_2011_RC70_SPRING	15-19	MC	40.1	UCOL	22.4	rock	18.0	GRIM	15.0	LR	4.0
Rock_2010_1281_004_SPRING	15-19	MC	41.9	ROCK	36.6	LR	15.2	GRIM	5.2	UCOL	0.9
Rock_2010_1281_005_SPRING	15-19	MC	42.7	UPSal	19.7	rock	19.5	LR	14.8	UCOL	1.7
Rock_2011_RC93_SPRING	15-19	MC	50.2	ROCK	48.9	UCOL	0.7	LR	0.1	GRIM	0.0
Rock_2009_1280_33_FALL	15-19	MC	51.4	ROCK	37.6	LR	7.3	GRIM	2.2	UPSal	1.5
Rock_2010_1281_002_SPRING	15-19	MC	53.7	ROCK	34.2	LR	7.5	GRIM	3.6	UCOL	0.8
Rock_2011_RC107_SPRING	15-19	MC	59.6	GRIM	19.6	UPSal	14.2	LR	3.0	rock	2.6
Omy_RockCr12-RC0395	15-19	MC	66.0	GRIM	12.7	rock	11.4	LR	9.5	UCOL	0.2
Omy_RockCr12-RC0394	15-19	MC	67.2	ROCK	31.7	UCOL	0.9	LR	0.2	UPSal	0.0
Rock_2011_RC104_SPRING	15-19	ROCK	32.5	LR	22.9	UPSal	15.6	UCOL	10.5	MC	8.8
Rock_2011_RC84_SPRING	15-19	ROCK	35.6	LR	26.6	MC	19.3	UCOL	17.6	GRIM	0.6
Rock_2011_RC68_SPRING	15-19	ROCK	43.1	LR	30.1	GRIM	16.7	UPSal	7.1	UCOL	2.7
Rock_2011_RC87_SPRING	15-19	ROCK	44.5	LR	28.8	MCSC	16.8	MC	4.4	UPSal	3.3
Rock_2011_RC106_SPRING	15-19	ROCK	44.7	UCOL	27.0	MC	13.2	GRIM	7.2	LR	6.0

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2011_RC79_SPRING	15-19	ROCK	45.4	LR	20.2	GRIM	17.0	UCOL	10.2	MC	7.0
Rock_2011_RC134_FALL	15-19	ROCK	46.3	LR	44.1	GRIM	6.4	MC	2.4	UPSal	0.7
Rock_2011_RC138_FALL	15-19	ROCK	47.7	LR	19.5	MCSC	14.0	MC	13.1	UCOL	2.6
Rock_2009_1280_45_FALL	15-19	ROCK	49.7	LR	41.5	GRIM	7.9	UCOL	0.7	UPSal	0.2
Rock_2009_1280_32_FALL	15-19	ROCK	50.6	LR	39.4	GRIM	6.1	UPSal	2.4	MC	1.1
Rock_2009_1280_35_FALL	15-19	ROCK	54.4	LR	34.7	GRIM	7.4	UPSal	1.2	MSSFS	0.9
Rock_2009_1280_50_FALL	15-19	ROCK	55.7	UPSal	31.7	GRIM	6.8	LR	5.6	MC	0.2
Rock_2009_1280_49_FALL	15-19	ROCK	58.4	GRIM	19.9	LR	15.5	UPSal	4.3	MC	1.6
Rock_2009_1280_42_FALL	15-19	ROCK	58.5	MC	28.8	LR	10.0	UCOL	2.1	GRIM	0.4
Rock_2011_RC77_SPRING	15-19	ROCK	60.1	GRIM	24.4	LR	13.9	MC	1.0	UCOL	0.5
Rock_2011_RC76_SPRING	15-19	ROCK	62.4	LR	26.1	MCSC	6.5	GRIM	4.0	UPSal	0.6
Omy_RockCr12-RC0390	15-19	ROCK	62.6	LR	19.3	UPSal	9.6	MC	5.5	UCOL	2.8
Rock_2011_RC96_SPRING	15-19	ROCK	64.0	GRIM	14.3	MC	12.0	LR	5.6	UCOL	3.5
Rock_2010_1281_012_SPRING	15-19	ROCK	65.0	MC	16.8	UPSal	7.1	GRIM	6.5	LR	4.0
Rock_2011_RC72_SPRING	15-19	ROCK	65.8	MC	31.8	UCOL	2.2	GRIM	0.1	LR	0.1
Rock_2010_1281_003_SPRING	15-19	ROCK	67.7	LR	26.7	GRIM	3.3	MC	1.4	UCOL	0.8
Rock_2009_1280_38_FALL	15-19	ROCK	72.0	LR	24.8	GRIM	1.6	UCOL	0.8	UPSal	0.5
Rock_2011_RC74_SPRING	15-19	ROCK	74.7	UCOL	10.3	LR	6.4	MC	5.4	UPSal	1.9
Rock_2011_RC81_SPRING	15-19	ROCK	74.9	UCOL	19.1	LR	4.1	MC	1.2	GRIM	0.4
Omy_RockCr12-RC0294	15-19	ROCK	**75.9**	LR	9.7	MC	7.0	GRIM	6.5	UCOL	0.7
Rock_2011_RC133_FALL	15-19	ROCK	**76.3**	LR	14.9	GRIM	5.2	MC	2.5	UPSal	0.8
Rock_2011_RC137_FALL	15-19	ROCK	**77.2**	MC	13.0	GRIM	5.1	LR	4.5	UCOL	0.1
Rock_2011_RC90_SPRING	15-19	ROCK	**78.9**	UPSal	9.1	GRIM	7.0	LR	2.9	MC	2.0
Rock_2011_RC83_SPRING	15-19	ROCK	**79.2**	GRIM	13.0	LR	5.9	MC	0.9	UCOL	0.8
Rock_2011_RC86_SPRING	15-19	ROCK	**79.8**	LR	9.2	UCOL	7.9	UPSal	1.7	MC	1.0
Rock_2011_RC82_SPRING	15-19	ROCK	**80.2**	UCOL	13.3	GRIM	3.6	LR	1.3	MC	0.9
Rock_2009_1280_41_FALL	15-19	ROCK	**81.7**	LR	16.5	GRIM	0.9	MC	0.8	MSSFS	0.1
Rock_2011_RC69_SPRING	15-19	ROCK	**83.3**	LR	10.4	GRIM	4.4	MC	1.2	UCOL	0.6
Rock_2011_RC97_SPRING	15-19	ROCK	**87.9**	LR	7.0	UPSal	2.7	GRIM	1.6	MC	0.4
Rock_2011_RC67_SPRING	15-19	ROCK	**89.0**	MC	7.3	LR	1.8	UCOL	1.0	GRIM	0.8
Rock_2011_RC92_SPRING	15-19	ROCK	**92.3**	LR	4.1	MC	3.3	UCOL	0.4	MCSC	0.0
Rock_2010_1281_011_SPRING	15-19	ROCK	**92.9**	MC	2.4	LR	2.2	UCOL	2.1	UPSal	0.2
Rock_2009_1280_39_FALL	15-19	ROCK	**93.0**	LR	3.4	MC	1.8	UPSal	1.0	UCOL	0.4
Omy_RockCr12-RC0296	15-19	ROCK	**93.4**	MC	4.6	GRIM	0.9	UCOL	0.5	LR	0.4
Rock_2009_1280_43_FALL	15-19	ROCK	**95.1**	LR	2.7	GRIM	1.0	UPSal	0.7	MC	0.5
Rock_2011_RC130_FALL	15-19	ROCK	**96.1**	GRIM	1.3	LR	1.2	MC	1.0	UPSal	0.5

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2010_1281_006_SPRING	15-19	ROCK	**96.2**	GRIM	1.7	MC	1.3	LR	0.6	UCOL	0.3
Rock_2011_RC73_SPRING	15-19	ROCK	**97.3**	MC	1.3	LR	0.5	GRIM	0.4	UPSal	0.4
Rock_2009_1280_31_FALL	15-19	ROCK	**97.5**	UCOL	1.3	LR	0.5	GRIM	0.3	MC	0.2
Rock_2011_RC91_SPRING	15-19	ROCK	**98.2**	LR	1.6	GRIM	0.1	MCSC	0.0	UCOL	0.0
Rock_2010_1281_009_SPRING	15-19	ROCK	**98.3**	LR	0.5	MC	0.5	UPSal	0.3	UCOL	0.3
Rock_2009_1280_44_FALL	15-19	UCOL	34.0	ROCK	26.2	GRIM	19.3	MC	13.9	LR	5.5
Omy_RockCr12-RC0291	15-19	UCOL	46.4	LR	23.3	GRIM	16.3	rock	12.3	MC	1.5
Rock_2011_RC129_FALL	15-19	UPSal	34.0	LR	24.3	GRIM	19.1	rock	14.4	MC	5.7
Rock_2010_1281_008_SPRING	15-19	UPSal	34.8	ROCK	27.5	LR	16.0	GRIM	9.3	MC	8.6
Rock_2011_RC88_SPRING	15-19	UPSal	43.4	LR	35.7	GRIM	15.3	rock	4.2	MCSC	1.1
Rock_2011_RC136_FALL	15-19	UPSal	44.7	GRIM	24.1	rock	12.8	LR	10.1	UCOL	7.2
Rock_2011_RC135_FALL	15-19	UPSal	47.1	ROCK	21.4	UCOL	11.6	LR	10.2	GRIM	4.9
Omy_RockCr12-RC0280	15-19	UPSal	49.4	GRIM	28.3	rock	11.5	LR	6.2	MC	3.9
Rock_2010_1281_007_SPRING	15-19	UPSal	51.8	ROCK	40.9	MC	3.4	LR	3.1	UCOL	0.4
Rock_2009_1280_36_FALL	15-19	UPSal	52.4	ROCK	43.1	UCOL	2.8	MC	0.9	LR	0.4
Rock_2011_RC132_FALL	15-19	UPSal	57.0	ROCK	19.4	LR	10.7	MC	9.2	UCOL	2.6
Rock_2011_RC140_FALL	15-19	UPSal	58.2	UCOL	17.5	LR	11.4	rock	11.2	GRIM	1.2
Rock_2009_1280_47_FALL	15-19	UPSal	62.0	ROCK	28.3	MC	4.3	LR	2.9	GRIM	1.8
Rock_2011_RC80_SPRING	15-19	UPSal	62.6	ROCK	34.3	GRIM	1.4	MC	1.0	LR	0.4
Rock_2011_RC131_FALL	15-19	UPSal	64.3	UCOL	15.9	LR	13.2	MC	3.3	rock	2.9
Rock_2011_RC71_SPRING	15-19	UPSal	70.2	LR	21.6	GRIM	3.3	rock	3.1	MCSC	1.3
Rock_2011_RC78_SPRING	15-19	UPSal	91.0	ROCK	4.5	GRIM	3.0	LR	1.3	UCOL	0.2
Rock_2011_RC94_SPRING	15-19	UPSal	99.9	ROCK	0.1	UCOL	0.0	MC	0.0	GRIM	0.0
Rock_2008_128_FALL	20-22	Ekone	76.0	ROCK	12.4	MC	6.5	LR	2.9	UCOL	1.1
Rock_2011_RC120_SPRING	20-22	GRIM	35.3	MSSFS	32.6	LR	14.2	rock	13.8	UCOL	1.8
Rock_2011_RC204_FALL	20-22	GRIM	37.5	ROCK	31.5	MC	22.1	LR	6.9	UCOL	1.4
Rock_2011_RC118_SPRING	20-22	GRIM	38.9	UCOL	21.4	MC	16.5	LR	13.6	rock	7.7
Rock_2008_121_FALL	20-22	GRIM	43.5	ROCK	26.5	LR	18.7	UCOL	9.2	MC	2.0
Rock_2008_116_FALL	20-22	GRIM	49.3	LR	40.3	UPSal	3.2	MC	3.1	rock	2.2
Rock_2011_RC201_FALL	20-22	GRIM	51.1	UPSal	30.4	LR	14.0	rock	3.0	MC	1.4
Omy_RockCr12-RC0287	20-22	GRIM	54.1	LR	37.5	MC	5.0	UCOL	2.2	rock	1.0
Rock_2008_114_FALL	20-22	GRIM	60.4	UCOL	20.6	LR	11.7	rock	4.6	MSSFS	1.6
Rock_2011_RC115_SPRING	20-22	GRIM	72.7	ROCK	15.7	LR	8.7	MC	1.4	UCOL	1.0
Rock_2008_141_FALL	20-22	LR	35.7	ROCK	34.1	UPSal	18.1	UCOL	7.1	GRIM	2.5
Rock_2011_RC113_SPRING	20-22	LR	37.0	UPSal	28.4	UCOL	16.4	rock	13.4	MC	3.0
Rock_2011_RC109_SPRING	20-22	LR	42.3	ROCK	38.8	MCSC	10.4	GRIM	5.5	UCOL	1.5

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2008_140_FALL	20-22	LR	42.7	UPSal	36.5	rock	14.9	MSSFS	2.7	UCOL	2.3
Rock_2008_143_FALL	20-22	LR	44.2	MC	40.6	UPSal	9.2	rock	4.3	GRIM	1.3
Rock_2008_108_FALL	20-22	LR	47.6	GRIM	18.0	MC	17.3	rock	14.8	UCOL	1.5
Rock_2008_145_FALL	20-22	LR	48.5	ROCK	34.8	GRIM	12.5	UPSal	2.2	UCOL	1.0
Rock_2008_148_FALL	20-22	LR	54.9	ROCK	20.5	MC	8.3	GRIM	8.0	UPSal	7.3
Rock_2011_RC209_FALL	20-22	LR	55.9	ROCK	21.9	UPSal	14.1	GRIM	7.1	MC	0.6
Rock_2009_1280_25_FALL	20-22	LR	72.9	ROCK	16.7	MC	6.5	UCOL	1.4	UPSal	1.3
Omy_RockCr12-RC0387	20-22	LR	76.7	ROCK	9.5	UPSal	6.4	GRIM	5.5	UCOL	1.1
Rock_2011_RC124_SPRING	20-22	LR	85.6	GRIM	6.4	UCOL	3.1	UPSal	2.8	MCSC	1.2
Rock_2011_RC122_SPRING	20-22	MC	33.1	ROCK	30.7	LR	23.9	UCOL	5.1	Quartz	2.9
Rock_2008_153_FALL	20-22	MC	33.7	ROCK	30.6	Quartz	11.3	LR	7.3	UCOL	7.3
Rock_2009_1280_24_FALL	20-22	MC	41.0	GRIM	29.1	rock	11.0	LR	10.2	UCOL	8.3
Rock_2008_122_FALL	20-22	MC	43.7	ROCK	31.1	GRIM	15.8	LR	7.0	UCOL	2.3
Rock_2008_146_FALL	20-22	MC	74.2	LR	20.8	UCOL	4.0	rock	0.9	GRIM	0.2
Rock_2008_110_FALL	20-22	MC	75.8	ROCK	21.1	LR	2.9	UCOL	0.1	GRIM	0.1
Rock_2008_105_FALL	20-22	MCSC	64.6	GRIM	14.2	rock	10.0	LR	9.2	UCOL	1.3
Rock_2008_120_FALL	20-22	MCSC	97.0	LR	1.4	rock	0.7	GRIM	0.5	UCOL	0.3
Rock_2011_RC210_FALL	20-22	Quartz	26.0	ROCK	25.7	GRIM	20.1	MC	13.9	LR	10.6
Rock_2008_109_FALL	20-22	Quartz	57.1	ROCK	42.0	LR	0.6	MC	0.2	GRIM	0.1
Rock_2008_132_FALL	20-22	ROCK	25.2	LR	23.4	UPSal	20.6	UCOL	20.3	GRIM	7.6
Rock_2009_1280_27_FALL	20-22	ROCK	30.4	GRIM	29.2	LR	18.1	UCOL	10.9	UPSal	10.8
Rock_2008_138_FALL	20-22	ROCK	30.8	MC	19.4	Quartz	17.5	LR	15.9	GRIM	8.8
Rock_2008_117_FALL	20-22	ROCK	32.8	LR	25.4	Quartz	17.0	MC	13.4	GRIM	8.2
Rock_2011_RC202_FALL	20-22	ROCK	34.4	LR	33.2	MC	19.7	MCSC	5.6	GRIM	4.3
Rock_2009_1280_22_FALL	20-22	ROCK	37.7	LR	21.3	GRIM	15.1	MSSFS	10.4	UPSal	7.3
Rock_2009_1280_26_FALL	20-22	ROCK	37.9	LR	25.8	UPSal	14.6	MSSFS	13.7	GRIM	7.4
Rock_2008_106_FALL	20-22	ROCK	39.6	LR	20.9	MC	19.7	UCOL	14.8	GRIM	4.5
Rock_2011_RC103_SPRING	20-22	ROCK	40.6	LR	34.8	MSSFS	22.1	MCSC	1.5	UCOL	0.6
Rock_2008_151_FALL	20-22	ROCK	41.1	MC	40.9	LR	7.9	UPSal	5.1	UCOL	4.2
Rock_2008_147_FALL	20-22	ROCK	41.2	LR	30.1	GRIM	15.9	MC	10.9	UPSal	1.2
Rock_2008_136_FALL	20-22	ROCK	43.0	GRIM	29.3	LR	26.8	MC	0.5	UCOL	0.3
Rock_2009_1280_23_FALL	20-22	ROCK	43.5	LR	30.7	UCOL	12.2	MC	7.7	GRIM	5.3
Rock_2008_118_FALL	20-22	ROCK	47.5	GRIM	34.7	LR	10.4	UPSal	4.1	UCOL	2.0
Rock_2011_RC121_SPRING	20-22	ROCK	48.2	MC	30.2	LR	18.9	UCOL	1.7	MCSC	0.6
Rock_2011_RC126_SPRING	20-22	ROCK	49.0	GRIM	40.7	UPSal	6.5	LR	3.3	UCOL	0.3
Rock_2011_RC128_SPRING	20-22	ROCK	51.1	LR	25.6	GRIM	11.3	MC	11.0	UPSal	0.8

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2008_152_FALL	20-22	ROCK	51.3	GRIM	26.8	MC	9.3	UCOL	5.7	LR	4.1
Rock_2011_RC114_SPRING	20-22	ROCK	52.8	GRIM	12.6	UPSal	12.1	LR	11.0	UCOL	10.9
Rock_2009_1280_29_FALL	20-22	ROCK	53.6	LR	17.7	UCOL	12.0	UPSal	7.9	GRIM	6.7
Rock_2011_RC119_SPRING	20-22	ROCK	53.7	LR	21.9	UCOL	9.5	GRIM	8.7	UPSal	5.5
Rock_2011_RC208_FALL	20-22	ROCK	56.3	MC	26.0	LR	16.4	UCOL	1.3	GRIM	0.0
Rock_2011_RC207_FALL	20-22	ROCK	58.2	UCOL	37.1	MC	2.3	GRIM	1.3	LR	0.9
Rock_2008_112_FALL	20-22	ROCK	60.7	UCOL	32.7	MC	5.8	GRIM	0.4	LR	0.2
Rock_2008_139_FALL	20-22	ROCK	61.2	GRIM	20.0	UPSal	16.2	LR	2.1	UCOL	0.3
Rock_2011_RC117_SPRING	20-22	ROCK	61.3	LR	14.9	GRIM	11.4	MC	8.3	UPSal	2.1
Rock_2008_124_FALL	20-22	ROCK	63.6	GRIM	22.4	MC	5.5	LR	5.1	UCOL	3.1
Rock_2011_RC111_SPRING	20-22	ROCK	64.2	LR	26.1	MC	8.5	GRIM	1.0	UCOL	0.0
Rock_2009_1280_21_FALL	20-22	ROCK	64.9	LR	19.8	MSSFS	9.9	GRIM	4.3	MC	1.0
Rock_2011_RC125_SPRING	20-22	ROCK	66.2	UCOL	18.8	LR	9.8	UPSal	1.8	GRIM	1.4
Rock_2011_RC110_SPRING	20-22	ROCK	67.0	UPSal	21.4	LR	5.6	GRIM	4.2	UCOL	1.6
Omy_RockCr12-RC0289	20-22	ROCK	68.2	LR	25.0	GRIM	5.0	Quartz	0.8	UPSal	0.6
Rock_2011_RC102_SPRING	20-22	ROCK	68.9	UPSal	19.5	MC	5.2	LR	2.4	MSSFS	1.9
Rock_2008_111_FALL	20-22	ROCK	69.9	UPSal	16.2	UCOL	8.8	MC	3.4	LR	1.5
Rock_2008_133_FALL	20-22	ROCK	70.9	LR	26.5	GRIM	1.6	MC	0.9	UCOL	0.0
Rock_2008_149_FALL	20-22	ROCK	71.5	MSSFS	14.1	LR	10.0	GRIM	2.3	UCOL	1.9
Rock_2008_137_FALL	20-22	ROCK	71.7	LR	10.6	UPSal	7.6	UCOL	4.6	MC	3.2
Rock_2008_107_FALL	20-22	ROCK	72.8	LR	18.8	MC	5.5	GRIM	1.3	Quartz	1.3
Rock_2008_155_FALL	20-22	ROCK	74.7	MC	13.3	LR	10.6	UCOL	0.9	UPSal	0.3
Rock_2009_1280_20_FALL	20-22	ROCK	**75.2**	MC	12.6	LR	6.5	GRIM	4.9	UPSal	0.6
Rock_2008_154_FALL	20-22	ROCK	**76.3**	UPSal	12.4	LR	5.1	GRIM	4.3	UCOL	1.4
Rock_2011_RC206_FALL	20-22	ROCK	**76.9**	LR	9.4	UPSal	9.0	GRIM	1.9	UCOL	1.4
Rock_2008_142_FALL	20-22	ROCK	**77.4**	MC	10.4	UCOL	4.5	UPSal	4.3	LR	2.5
Omy_RockCr12-RC0398	20-22	ROCK	**79.1**	LR	11.0	MC	6.5	GRIM	2.0	UPSal	1.1
Rock_2008_123_FALL	20-22	ROCK	**79.5**	MC	13.6	UCOL	6.3	LR	0.6	UPSal	0.1
Rock_2008_115_FALL	20-22	ROCK	**82.5**	MC	10.7	UCOL	4.8	LR	1.5	UPSal	0.5
Rock_2011_RC123_SPRING	20-22	ROCK	**83.8**	LR	9.2	MC	4.6	GRIM	1.1	UCOL	0.7
Rock_2011_RC116_SPRING	20-22	ROCK	**85.4**	GRIM	4.9	LR	4.4	MC	2.7	UPSal	1.9
Rock_2008_127_FALL	20-22	ROCK	**85.5**	MC	8.7	UCOL	4.8	GRIM	0.5	LR	0.3
Rock_2011_RC112_SPRING	20-22	ROCK	**86.1**	MC	8.8	LR	2.5	UCOL	1.5	GRIM	0.7
Rock_2008_125_FALL	20-22	ROCK	**87.6**	UPSal	7.6	LR	3.6	UCOL	0.6	MC	0.4
Rock_2008_129_FALL	20-22	ROCK	**87.6**	UPSal	7.6	LR	3.6	UCOL	0.6	MC	0.4
Rock_2011_RC99_SPRING	20-22	ROCK	**88.8**	GRIM	6.2	MC	2.4	LR	1.5	UPSal	0.5

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Rock_2008_130_FALL	20-22	ROCK	**88.9**	MC	6.2	LR	3.0	UCOL	0.7	GRIM	0.6
Rock_2008_135_FALL	20-22	ROCK	**89.0**	LR	5.2	GRIM	4.7	UPSal	0.5	MCSC	0.4
Rock_2009_1280_28_FALL	20-22	ROCK	**91.6**	UPSal	3.6	LR	2.2	GRIM	1.3	MC	1.2
Rock_2011_RC101_SPRING	20-22	ROCK	**92.1**	LR	7.3	MC	0.3	GRIM	0.3	UCOL	0.1
Rock_2008_119_FALL	20-22	ROCK	**92.1**	MCSC	2.5	UCOL	2.1	MC	2.0	LR	1.3
Rock_2011_RC205_FALL	20-22	ROCK	**97.0**	GRIM	1.8	UCOL	0.6	LR	0.4	UPSal	0.2
Omy_RockCr12-RC0285	20-22	ROCK	**97.2**	MC	1.0	LR	0.8	UPSal	0.6	GRIM	0.2
Rock_2008_150_FALL	20-22	UCOL	41.8	ROCK	19.1	GRIM	13.8	Quartz	12.2	LR	8.2
Rock_2011_RC127_SPRING	20-22	UCOL	67.1	ROCK	18.6	MC	13.3	LR	0.5	GRIM	0.2
Rock_2008_126_FALL	20-22	UPSal	27.4	UCOL	19.3	GRIM	19.1	LR	17.4	MC	13.3
Rock_2008_144_FALL	20-22	UPSal	36.6	ROCK	34.0	GRIM	25.8	LR	3.1	MSSFS	0.3
Rock_2008_113_FALL	20-22	UPSal	47.7	GRIM	27.0	LR	12.6	MSSFS	8.3	rock	3.4
Rock_2011_RC203_FALL	20-22	UPSal	48.4	ROCK	41.2	UCOL	7.3	LR	1.9	MC	1.1
Rock_2011_RC100_SPRING	20-22	UPSal	52.2	ROCK	25.3	LR	9.8	UCOL	6.5	GRIM	5.7
Rock_2008_131_FALL	20-22	UPSal	77.8	ROCK	14.9	MC	2.9	LR	2.5	UCOL	1.6
Rock_2009_1280_30_FALL	20-22	UPSal	80.4	ROCK	9.5	LR	8.0	MC	1.0	GRIM	0.8
Rock_2008_134_FALL	20-22	UPSal	96.3	ROCK	2.4	GRIM	1.1	LR	0.2	UCOL	0.0
Squaw_2011_RC25_SPRING	S0-2	GRIM	31.4	UPSal	20.6	MC	16.8	rock	15.5	UCOL	13.1
Squaw_2011_RC38_SPRING	S0-2	GRIM	34.6	LR	24.7	MSSFS	16.2	UCOL	10.8	UPSal	6.5
Squaw_2008_85_FALL	S0-2	GRIM	41.3	ROCK	32.2	UPSal	12.4	LR	7.5	MC	3.2
Squaw_2008_94_FALL	S0-2	GRIM	41.4	ROCK	30.8	UCOL	15.5	MC	9.8	LR	2.3
Squaw_2010_1281_014_SPRING	S0-2	GRIM	49.7	ROCK	20.6	LR	17.0	UPSal	9.9	MC	2.3
Squaw_2010_1281_040_SPRING	S0-2	GRIM	74.4	LR	20.2	rock	2.7	MC	0.9	UCOL	0.9
Squaw_2010_1281_041_SPRING	S0-2	GRIM	76.8	LR	19.1	UCOL	2.0	MC	1.3	rock	0.4
Omy_RockCr12-RC0369	S0-2	GRIM	78.0	LR	16.3	rock	2.3	UCOL	2.2	MSSFS	0.5
Squaw_2008_75_FALL	S0-2	LR	34.9	MCSC	26.0	UCOL	19.7	rock	8.7	UPSal	6.1
Squaw_2010_1281_036_SPRING	S0-2	LR	38.3	MCSC	28.9	GRIM	20.5	rock	7.1	UCOL	3.4
Squaw_2008_73_FALL	S0-2	LR	42.6	ROCK	21.7	UCOL	21.5	UPSal	8.8	GRIM	4.8
Omy_RockCr12-RC0374	S0-2	LR	42.6	UCOL	25.3	rock	13.3	MC	9.8	GRIM	7.3
Omy_RockCr12-RC0379	S0-2	LR	44.3	GRIM	27.4	rock	17.6	MCSC	5.0	UCOL	3.6
Omy_RockCr12-RC0270	S0-2	LR	44.3	ROCK	34.8	MC	19.9	GRIM	0.4	UPSal	0.3
Rock_2011_RC12_SPRING	S0-2	LR	45.0	ROCK	38.1	UPSal	11.2	MC	3.0	GRIM	2.1
Squaw_2011_RC41_SPRING	S0-2	LR	45.0	ROCK	25.0	GRIM	19.0	MC	6.7	UPSal	3.9
Squaw_2008_95_FALL	S0-2	LR	45.9	GRIM	20.8	rock	17.7	UCOL	6.8	UPSal	5.9
Squaw_2011_RC143_FALL	S0-2	LR	48.3	ROCK	26.5	UCOL	19.6	UPSal	2.6	GRIM	2.5
Squaw_2008_38_FALL	S0-2	LR	52.3	ROCK	44.4	GRIM	2.8	MCSC	0.5	MC	0.0

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Squaw_2008_46_FALL	S0-2	LR	52.7	GRIM	16.2	MC	15.9	UCOL	7.5	rock	6.9
Squaw_2008_54_FALL	S0-2	LR	54.6	UPSal	41.6	GRIM	2.1	rock	1.2	UCOL	0.5
Squaw_2010_1281_027_SPRING	S0-2	LR	57.2	ROCK	17.2	GRIM	14.9	MC	5.1	UCOL	4.0
Squaw_2008_91_FALL	S0-2	LR	60.0	ROCK	16.2	GRIM	14.5	UCOL	5.4	MC	3.6
Rock_2011_RC46_SPRING	S0-2	LR	60.6	MC	20.9	rock	12.2	GRIM	3.8	UCOL	2.2
Squaw_2011_RC30_SPRING	S0-2	LR	67.6	GRIM	16.1	rock	13.2	MC	2.1	UPSal	0.6
Squaw_2011_RC29_SPRING	S0-2	LR	85.1	GRIM	10.1	MCSC	2.1	rock	1.0	UPSal	1.0
Omy_RockCr12-RC0376	S0-2	LR	85.5	UPSal	6.6	GRIM	3.4	MC	2.9	UCOL	1.2
Squaw_2010_1281_034_SPRING	S0-2	LR	88.8	ROCK	4.8	GRIM	3.5	UCOL	1.4	UPSal	0.7
Squaw_2008_80_FALL	S0-2	MC	40.6	ROCK	24.9	GRIM	18.7	LR	14.7	UCOL	0.8
Squaw_2008_51_FALL	S0-2	MC	43.0	ROCK	23.4	LR	15.0	UCOL	14.3	UPSal	4.0
Squaw_2008_86_FALL	S0-2	MC	49.2	LR	14.6	GRIM	14.3	UCOL	12.4	rock	9.4
Squaw_2008_70_FALL	S0-2	MC	59.1	UCOL	27.0	LR	7.5	rock	3.0	GRIM	3.0
Squaw_2011_RC31_SPRING	S0-2	MC	61.4	ROCK	37.8	LR	0.7	GRIM	0.1	UCOL	0.0
Squaw_2010_1281_029_SPRING	S0-2	MC	64.0	ROCK	16.5	UCOL	8.8	LR	6.1	GRIM	4.6
Squaw_2011_RC34_SPRING	S0-2	MC	64.0	ROCK	19.1	UCOL	15.3	LR	1.0	GRIM	0.6
Omy_RockCr12-RC0265	S0-2	MC	65.9	GRIM	28.6	LR	3.6	rock	0.9	UPSal	0.5
Squaw_2010_1281_037_SPRING	S0-2	MCSC	38.9	LR	28.2	rock	15.3	UCOL	11.3	MC	4.3
Squaw_2011_RC36_SPRING	S0-2	MCSC	43.9	LR	33.9	GRIM	9.5	UPSal	7.1	UCOL	4.4
Squaw_2008_83_FALL	S0-2	MCSC	68.2	LR	18.5	GRIM	8.6	UCOL	2.2	rock	2.0
Squaw_2008_79_FALL	S0-2	MCSC	68.8	LR	19.3	Quartz	5.2	rock	3.1	GRIM	1.9
Rock_2011_RC08_SPRING	S0-2	MCSC	92.6	ROCK	6.5	LR	0.7	UPSal	0.2	GRIM	0.0
Squaw_2008_50_FALL	S0-2	MCSC	98.2	ROCK	1.0	LR	0.6	GRIM	0.1	UPSal	0.0
Squaw_2008_93_FALL	S0-2	MCSC	99.3	ROCK	0.5	LR	0.2	GRIM	0.0	UPSal	0.0
Squaw_2011_RC150_FALL	S0-2	MCSC	99.8	ROCK	0.1	LR	0.1	UPSal	0.0	GRIM	0.0
Squaw_2010_1281_035_SPRING	S0-2	MSSFS	96.8	UPSal	2.8	LR	0.2	GRIM	0.1	rock	0.1
Squaw_2011_RC26_SPRING	S0-2	ROCK	35.1	MC	25.7	GRIM	15.1	LR	14.5	UCOL	8.3
Squaw_2008_81_FALL	S0-2	ROCK	38.3	LR	22.8	MSSFS	18.1	UPSal	11.1	MC	6.2
Squaw_2008_45_FALL	S0-2	ROCK	40.0	LR	27.1	GRIM	17.3	UCOL	10.4	UPSal	4.9
Squaw_2008_55_FALL	S0-2	ROCK	40.5	UPSal	18.9	LR	16.8	GRIM	16.3	MC	6.3
Rock_2011_RC47_SPRING	S0-2	ROCK	40.6	LR	26.9	GRIM	26.6	MC	4.1	UCOL	1.0
Squaw_2008_60_FALL	S0-2	ROCK	45.7	GRIM	28.7	MC	12.9	LR	9.5	UCOL	2.7
Omy_RockCr12-RC0239	S0-2	ROCK	46.1	LR	30.4	MC	10.5	UCOL	6.5	GRIM	5.3
Squaw_2008_37_FALL	S0-2	ROCK	46.3	GRIM	23.9	LR	17.3	UPSal	9.7	UCOL	1.9
Squaw_2008_59_FALL	S0-2	ROCK	46.4	LR	16.0	MC	15.4	GRIM	13.2	UCOL	4.3
Squaw_2008_64_FALL	S0-2	ROCK	48.1	GRIM	21.4	MSSFS	19.4	LR	7.2	UPSal	3.6

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Omy_RockCr12-RC0409	S0-2	ROCK	48.9	UCOL	31.3	UPSal	16.7	LR	1.9	MC	1.1
Squaw_2010_1281_039_SPRING	S0-2	ROCK	48.9	GRIM	34.5	UPSal	8.8	MSSFS	3.2	LR	2.4
Squaw_2008_61_FALL	S0-2	ROCK	49.2	LR	33.8	UPSal	8.1	GRIM	4.0	UCOL	2.7
Omy_RockCr12-RC0275	S0-2	ROCK	49.8	LR	42.9	GRIM	4.9	MC	1.2	UCOL	0.5
Squaw_2008_96_FALL	S0-2	ROCK	50.9	GRIM	23.3	UPSal	13.8	LR	5.8	MC	5.0
Squaw_2008_92_FALL	S0-2	ROCK	51.9	MCSC	31.6	LR	14.4	UPSal	1.2	MC	0.3
Rock_2011_RC11_SPRING	S0-2	ROCK	55.8	UPSal	25.8	GRIM	10.3	MC	5.5	LR	2.0
Squaw_2011_RC141_FALL	S0-2	ROCK	56.1	LR	18.0	UCOL	12.6	UPSal	7.3	MC	3.5
Squaw_2008_74_FALL	S0-2	ROCK	56.2	LR	39.1	UPSal	2.2	MCSC	1.2	MC	1.1
Squaw_2008_39_FALL	S0-2	ROCK	56.8	UPSal	26.5	MC	14.4	LR	1.5	GRIM	0.9
Squaw_2008_41_FALL	S0-2	ROCK	56.9	UPSal	36.6	MC	5.1	LR	1.2	UCOL	0.2
Squaw_2008_66_FALL	S0-2	ROCK	58.5	LR	22.2	UCOL	8.1	GRIM	5.6	UPSal	4.8
Squaw_2011_RC149_FALL	S0-2	ROCK	59.1	LR	21.5	UCOL	7.1	MC	6.6	GRIM	4.7
Squaw_2011_RC148_FALL	S0-2	ROCK	59.7	MC	29.4	UCOL	10.1	GRIM	0.6	LR	0.2
Squaw_2008_84_FALL	S0-2	ROCK	61.5	LR	29.7	GRIM	5.1	MC	3.2	UPSal	0.4
Squaw_2011_RC145_FALL	S0-2	ROCK	62.6	LR	19.0	GRIM	14.6	UPSal	2.8	MC	0.5
Omy_RockCr12-RC0375	S0-2	ROCK	63.1	GRIM	22.0	LR	11.1	MC	2.2	UCOL	1.3
Squaw_2008_90_FALL	S0-2	ROCK	63.4	LR	14.6	UCOL	12.1	MC	9.7	MCSC	0.1
Squaw_2011_RC24_SPRING	S0-2	ROCK	63.7	MC	32.3	UPSal	1.6	UCOL	1.5	LR	0.8
Squaw_2011_RC32_SPRING	S0-2	ROCK	64.0	LR	16.2	GRIM	14.9	MC	2.9	UPSal	1.9
Squaw_2010_1281_015_SPRING	S0-2	ROCK	64.0	UCOL	16.0	MC	11.0	LR	6.2	GRIM	1.5
Squaw_2008_98_FALL	S0-2	ROCK	66.9	MC	16.6	UPSal	6.9	GRIM	6.3	LR	2.9
Squaw_2011_RC35_SPRING	S0-2	ROCK	69.5	MC	23.0	UCOL	6.2	UPSal	0.7	LR	0.5
Omy_RockCr12-RC0237	S0-2	ROCK	69.9	GRIM	15.6	LR	8.2	MC	3.0	MCSC	1.8
Squaw_2008_65_FALL	S0-2	ROCK	71.4	MC	24.3	UCOL	3.2	LR	0.9	GRIM	0.2
Rock_2011_RC07_SPRING	S0-2	ROCK	72.1	MC	11.0	UPSal	10.5	GRIM	2.7	UCOL	1.8
Squaw_2008_42_FALL	S0-2	ROCK	73.2	UCOL	14.0	MC	10.5	LR	2.0	GRIM	0.2
Squaw_2011_RC33_SPRING	S0-2	ROCK	73.4	LR	16.9	MC	7.2	GRIM	1.4	UCOL	1.0
Squaw_2010_1281_031_SPRING	S0-2	ROCK	73.9	LR	16.5	MC	4.8	UPSal	3.4	GRIM	0.7
Squaw_2011_RC27_SPRING	S0-2	ROCK	74.9	MC	11.8	GRIM	11.3	LR	1.4	UPSal	0.6
Squaw_2008_36_FALL	S0-2	ROCK	**76.0**	LR	18.0	GRIM	4.5	UPSal	0.9	MC	0.5
Squaw_2008_97_FALL	S0-2	ROCK	**76.1**	UCOL	8.8	LR	6.0	GRIM	3.7	MC	3.6
Rock_2011_RC48_SPRING	S0-2	ROCK	**76.2**	LR	16.1	UCOL	2.4	MCSC	2.3	MC	1.3
Omy_RockCr12-RC0372	S0-2	ROCK	**77.3**	UCOL	11.9	MC	5.6	LR	3.2	MCSC	1.1
Rock_2011_RC13_SPRING	S0-2	ROCK	**77.5**	UCOL	12.3	UPSal	4.8	MC	2.8	LR	2.4
Squaw_2008_102_FALL	S0-2	ROCK	**77.9**	LR	7.6	UPSal	7.1	MC	6.2	UCOL	0.8

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Omy_RockCr12-RC0368	S0-2	ROCK	**78.1**	MCSC	15.9	LR	3.5	MC	1.9	GRIM	0.4
Squaw_2011_RC28_SPRING	S0-2	ROCK	**78.1**	UCOL	14.7	MC	5.7	LR	0.7	GRIM	0.4
Squaw_2010_1281_038_SPRING	S0-2	ROCK	**78.6**	GRIM	10.8	LR	8.6	UCOL	1.5	MC	0.3
Squaw_2008_40_FALL	S0-2	ROCK	**78.7**	LR	12.3	MC	5.7	UCOL	1.7	UPSal	1.1
Squaw_2008_88_FALL	S0-2	ROCK	**81.9**	LR	5.0	MC	4.6	GRIM	3.8	UPSal	3.6
Rock_2011_RC09_SPRING	S0-2	ROCK	**82.0**	GRIM	9.9	LR	3.3	Quartz	2.9	MC	1.3
Squaw_2008_69_FALL	S0-2	ROCK	**83.6**	MC	10.3	UCOL	2.0	LR	1.9	GRIM	1.9
Squaw_2008_52_FALL	S0-2	ROCK	**84.0**	UCOL	11.6	MC	3.5	GRIM	0.7	LR	0.1
Squaw_2008_44_FALL	S0-2	ROCK	**84.1**	LR	7.9	GRIM	7.4	MC	0.6	MCSC	0.0
Squaw_2008_47_FALL	S0-2	ROCK	**84.4**	UCOL	8.2	MC	4.6	LR	1.7	GRIM	0.6
Omy_RockCr12-RC0264	S0-2	ROCK	**85.1**	GRIM	8.6	UPSal	3.8	LR	1.4	UCOL	1.0
Squaw_2011_RC144_FALL	S0-2	ROCK	**85.3**	MC	7.6	LR	3.4	GRIM	2.5	Quartz	0.7
Squaw_2008_77_FALL	S0-2	ROCK	**86.5**	UCOL	5.6	MC	4.0	GRIM	3.5	LR	0.4
Squaw_2008_49_FALL	S0-2	ROCK	**86.8**	LR	8.6	GRIM	2.5	UPSal	1.9	MSSFS	0.1
Squaw_2008_71_FALL	S0-2	ROCK	**86.9**	LR	11.8	MC	0.9	UCOL	0.2	UPSal	0.1
Squaw_2011_RC142_FALL	S0-2	ROCK	**87.1**	LR	10.5	MCSC	1.4	UPSal	0.3	MC	0.3
Omy_RockCr12-RC0410	S0-2	ROCK	**87.8**	LR	5.7	MCSC	3.1	GRIM	3.0	MC	0.3
Squaw_2008_89_FALL	S0-2	ROCK	**88.3**	UPSal	3.5	LR	2.5	GRIM	2.1	MC	2.0
Rock_2011_RC10_SPRING	S0-2	ROCK	**88.3**	UCOL	9.3	MC	1.3	LR	0.8	GRIM	0.2
Squaw_2011_RC39_SPRING	S0-2	ROCK	**88.7**	GRIM	5.2	MC	3.0	LR	1.7	UCOL	1.1
Squaw_2008_104_FALL	S0-2	ROCK	**88.8**	MC	7.7	LR	2.1	UCOL	1.3	GRIM	0.0
Squaw_2010_1281_013_SPRING	S0-2	ROCK	**88.9**	MC	7.1	UCOL	1.7	GRIM	1.6	LR	0.6
Squaw_2011_RC37_SPRING	S0-2	ROCK	**89.1**	LR	6.4	UCOL	2.6	GRIM	1.1	MC	0.5
Squaw_2008_35_FALL	S0-2	ROCK	**89.2**	MC	6.9	UCOL	1.3	GRIM	1.2	LR	1.2
Squaw_2010_1281_030_SPRING	S0-2	ROCK	**89.7**	UCOL	4.2	LR	3.4	GRIM	2.7	MC	0.1
Omy_RockCr12-RC0370	S0-2	ROCK	**89.8**	LR	5.3	UPSal	3.4	MCSC	0.8	UCOL	0.5
Squaw_2011_RC40_SPRING	S0-2	ROCK	**90.4**	GRIM	8.1	LR	0.8	UPSal	0.4	MC	0.2
Rock_2011_RC42_SPRING	S0-2	ROCK	**90.9**	LR	3.9	UCOL	2.0	MC	1.3	GRIM	1.0
Squaw_2008_100_FALL	S0-2	ROCK	**91.1**	LR	6.3	MC	1.9	GRIM	0.5	UCOL	0.1
Squaw_2010_1281_033_SPRING	S0-2	ROCK	**91.2**	UCOL	4.9	LR	1.4	MC	1.1	UPSal	1.0
Omy_RockCr12-RC0406	S0-2	ROCK	**92.0**	MC	4.8	GRIM	1.6	LR	1.0	UCOL	0.4
Squaw_2008_68_FALL	S0-2	ROCK	**93.2**	MC	3.6	LR	1.5	GRIM	1.0	UCOL	0.4
Squaw_2008_53_FALL	S0-2	ROCK	**93.6**	MC	4.6	LR	0.8	GRIM	0.7	UPSal	0.3
Squaw_2008_78_FALL	S0-2	ROCK	**93.8**	LR	2.4	UPSal	1.7	GRIM	1.6	MC	0.5
Omy_RockCr12-RC0380	S0-2	ROCK	**94.1**	MC	5.5	LR	0.3	UCOL	0.1	UPSal	0.0
Squaw_2011_RC147_FALL	S0-2	ROCK	**95.4**	LR	2.8	MC	1.2	GRIM	0.4	UPSal	0.1

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Squaw_2008_103_FALL	S0-2	ROCK	**95.5**	LR	2.0	GRIM	1.1	UPSal	0.9	Quartz	0.2
Squaw_2010_1281_032_SPRING	S0-2	ROCK	**96.7**	UCOL	1.8	LR	0.6	UPSal	0.4	GRIM	0.3
Squaw_2008_57_FALL	S0-2	ROCK	**96.8**	LR	2.0	GRIM	0.6	UPSal	0.4	MC	0.2
Rock_2011_RC45_SPRING	S0-2	ROCK	**98.6**	UCOL	0.5	GRIM	0.4	LR	0.3	MC	0.1
Squaw_2010_1281_016_SPRING	S0-2	ROCK	**98.7**	LR	0.7	UCOL	0.3	GRIM	0.2	MC	0.1
Squaw_2008_62_FALL	S0-2	ROCK	**98.9**	MC	0.5	UCOL	0.3	LR	0.1	GRIM	0.1
Squaw_2008_58_FALL	S0-2	UCOL	32.8	GRIM	21.6	rock	20.9	LR	16.8	MC	7.7
Omy_RockCr12-RC0401	S0-2	UCOL	36.5	MCSC	24.1	LR	23.8	rock	8.2	UPSal	4.7
Squaw_2010_1281_017_SPRING	S0-2	UCOL	61.8	ROCK	24.1	LR	5.3	GRIM	5.0	MC	3.5
Squaw_2008_76_FALL	S0-2	UCOL	63.0	GRIM	15.9	LR	12.3	rock	5.4	MC	3.3
Squaw_2008_48_FALL	S0-2	UCOL	76.3	LR	12.8	rock	4.5	MC	3.4	MCSC	2.2
Squaw_2008_56_FALL	S0-2	UCOL	80.2	MC	16.9	rock	2.2	LR	0.4	GRIM	0.3
Squaw_2008_72_FALL	S0-2	UPSal	26.2	UCOL	22.8	MC	20.5	LR	15.9	GRIM	8.5
Squaw_2008_87_FALL	S0-2	UPSal	39.0	UCOL	34.8	rock	14.6	LR	9.7	GRIM	1.5
Squaw_2010_1281_028_SPRING	S0-2	UPSal	46.1	ROCK	26.5	UCOL	12.2	LR	7.9	GRIM	3.8
Omy_RockCr12-RC0363	S0-2	UPSal	54.4	ROCK	40.7	LR	3.8	UCOL	0.8	MC	0.1
Squaw_2008_43_FALL	S0-2	UPSal	55.2	ROCK	37.0	MC	2.9	LR	2.3	GRIM	2.2
Squaw_2008_67_FALL	S0-2	UPSal	55.3	GRIM	31.5	MSSFS	5.1	LR	3.7	rock	3.6
Rock_2011_RC44_SPRING	S0-2	UPSal	61.7	ROCK	30.0	LR	5.0	GRIM	2.5	UCOL	0.6
Rock_2011_RC43_SPRING	S0-2	UPSal	64.5	MC	22.0	rock	8.7	UCOL	4.5	LR	0.3
Squaw_2008_63_FALL	S0-2	UPSal	65.4	ROCK	16.1	GRIM	11.0	MSSFS	3.7	LR	3.1
Squaw_2008_101_FALL	S0-2	UPSal	65.5	LR	20.9	UCOL	6.8	rock	5.6	MC	0.8
Omy_RockCr12-RC0408	S0-2	UPSal	65.6	ROCK	32.8	LR	1.3	GRIM	0.2	MC	0.1
Omy_RockCr12-RC0274	S0-2	UPSal	67.7	ROCK	24.5	GRIM	4.9	LR	1.7	UCOL	0.8
Squaw_2011_RC146_FALL	S0-2	UPSal	81.8	ROCK	12.6	LR	1.9	GRIM	1.8	UCOL	1.8
Squaw_2008_99_FALL	S0-2	UPSal	82.0	GRIM	6.6	LR	6.0	rock	3.5	UCOL	1.2
Squaw_2008_82_FALL	S0-2	UPSal	93.3	ROCK	6.0	GRIM	0.3	LR	0.3	UCOL	0.1
Omy_RockCr12-RC0359	S2-8	GRIM	37.6	ROCK	24.4	UPSal	20.2	LR	12.0	UCOL	3.4
Squaw_2010_1281_047_SPRING	S2-8	GRIM	45.9	MC	27.4	rock	17.6	LR	8.3	UCOL	0.5
Squaw_2010_1281_043_SPRING	S2-8	GRIM	46.0	UPSal	28.3	LR	10.0	UCOL	8.8	rock	4.4
Squaw_2010_1281_044_SPRING	S2-8	GRIM	46.9	ROCK	37.6	MC	10.1	LR	4.4	UCOL	0.8
Omy_RockCr12-RC0321	S2-8	GRIM	47.4	LR	28.0	UPSal	12.9	rock	8.9	MC	2.1
Omy_RockCr12-RC0421	S2-8	GRIM	59.4	LR	20.1	UCOL	14.7	UPSal	2.7	rock	2.7
Omy_RockCr12-RC0348	S2-8	GRIM	59.4	LR	22.2	UCOL	12.9	rock	2.5	MSSFS	2.0
Omy_RockCr12-RC0300	S2-8	GRIM	60.4	LR	25.3	rock	7.8	UCOL	6.2	MC	0.3
Omy_RockCr12-RC0333	S2-8	GRIM	64.8	ROCK	21.7	MC	10.3	LR	2.5	UPSal	0.7

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Omy_RockCr12-RC0427	S2-8	GRIM	65.5	UCOL	19.0	LR	6.5	rock	5.7	MC	1.9
Squaw_2011_RC157_FALL	S2-8	LR	34.8	MCSC	19.8	MC	14.2	rock	10.2	UCOL	9.2
Squaw_2009_1280_010_FALL	S2-8	LR	39.8	MC	26.8	rock	17.7	UCOL	10.0	UPSal	4.7
Squaw_2010_1281_042_SPRING	S2-8	LR	40.0	ROCK	30.3	MC	14.3	UCOL	12.3	GRIM	2.0
Omy_RockCr12-RC0297	S2-8	LR	42.0	UPSal	22.1	rock	15.0	MC	10.8	GRIM	8.7
Squaw_2009_1280_017_FALL	S2-8	LR	42.0	ROCK	29.0	UPSal	27.7	GRIM	0.6	MC	0.4
Omy_RockCr12-RC0384	S2-8	LR	45.6	ROCK	37.2	MC	13.6	UPSal	3.1	UCOL	0.3
Omy_RockCr12-RC0302	S2-8	LR	47.8	ROCK	41.8	MC	5.6	MSSFS	3.3	GRIM	1.0
Squaw_2009_1280_003_FALL	S2-8	LR	48.1	ROCK	38.5	MC	7.3	UCOL	4.0	UPSal	1.7
Omy_RockCr12-RC0354	S2-8	LR	49.7	UPSal	29.8	rock	10.1	GRIM	4.5	MC	3.7
Squaw_2009_1280_009_FALL	S2-8	LR	50.2	ROCK	16.1	GRIM	16.0	UPSal	10.1	MCSC	4.8
Omy_RockCr12-RC0310	S2-8	LR	63.3	UPSal	12.9	GRIM	10.5	rock	9.6	MC	2.8
Omy_RockCr12-RC0362	S2-8	MC	36.8	UCOL	26.5	rock	23.5	LR	8.2	GRIM	3.4
Omy_RockCr12-RC0418	S2-8	MC	44.6	ROCK	34.7	LR	18.8	UCOL	1.1	GRIM	0.7
Omy_RockCr12-RC0306	S2-8	MC	50.7	LR	30.3	rock	13.8	GRIM	2.9	UCOL	1.4
Squaw_2011_RC155_FALL	S2-8	MC	51.7	ROCK	20.3	LR	11.4	UPSal	8.0	GRIM	5.5
Squaw_2009_1280_008_FALL	S2-8	MC	55.2	ROCK	42.1	LR	1.0	UPSal	0.9	UCOL	0.7
Squaw_2009_1280_001_FALL	S2-8	MC	72.6	ROCK	12.8	UCOL	9.6	LR	3.7	GRIM	0.8
Omy_RockCr12-RC0352	S2-8	MC	76.0	ROCK	8.2	UCOL	7.1	GRIM	5.9	LR	1.5
Omy_RockCr12-RC0347	S2-8	MC	83.1	GRIM	7.7	LR	6.3	rock	1.8	UPSal	0.8
Omy_RockCr12-RC0353	S2-8	MC	88.9	UCOL	8.9	rock	1.9	LR	0.2	UPSal	0.1
Squaw_2009_1280_014_FALL	S2-8	MCSC	87.7	LR	4.6	UCOL	4.2	MC	2.1	GRIM	0.8
Squaw_2009_1280_002_FALL	S2-8	MCSC	90.6	LR	4.7	UCOL	2.1	rock	1.5	GRIM	0.6
Squaw_2009_1280_006_FALL	S2-8	ROCK	29.2	LR	26.9	UCOL	15.3	MC	14.1	GRIM	8.7
Squaw_2009_1280_005_FALL	S2-8	ROCK	34.4	MC	32.5	GRIM	25.7	LR	5.8	UCOL	1.1
Squaw_2009_1280_012_FALL	S2-8	ROCK	36.2	LR	36.2	UPSal	17.6	GRIM	4.8	UCOL	2.8
Omy_RockCr12-RC0255	S2-8	ROCK	37.4	LR	23.6	UCOL	15.0	UPSal	10.6	MC	7.3
Squaw_2011_RC161_FALL	S2-8	ROCK	38.2	MC	26.5	UCOL	23.3	LR	6.2	GRIM	3.2
Squaw_2009_1280_004_FALL	S2-8	ROCK	40.3	GRIM	27.4	LR	20.6	UPSal	11.0	MC	0.3
Omy_RockCr12-RC0419	S2-8	ROCK	41.7	MC	35.3	UPSal	8.7	GRIM	6.2	UCOL	4.8
Squaw_2010_1281_048_SPRING	S2-8	ROCK	45.6	UPSal	41.9	GRIM	5.7	MC	4.0	LR	2.5
Omy_RockCr12-RC0334	S2-8	ROCK	48.6	LR	23.3	MC	12.8	GRIM	9.2	UCOL	5.4
Omy_RockCr12-RC0317	S2-8	ROCK	48.9	UPSal	18.6	UCOL	13.4	LR	11.9	MC	4.7
Omy_RockCr12-RC0320	S2-8	ROCK	49.2	MC	18.4	LR	18.2	UPSal	11.9	GRIM	1.9
Omy_RockCr12-RC0349	S2-8	ROCK	51.5	GRIM	19.5	UCOL	16.3	MC	7.3	LR	5.2
Squaw_2010_1281_049_SPRING	S2-8	ROCK	54.1	LR	21.8	GRIM	19.3	MC	3.4	UCOL	0.8

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Squaw_2010_1281_051_SPRING	S2-8	ROCK	54.4	GRIM	19.6	LR	19.5	UPSal	4.7	MC	1.4
Omy_RockCr12-RC0330	S2-8	ROCK	54.5	LR	15.7	MC	13.3	MSSFS	9.3	GRIM	3.8
Squaw_2011_RC63_SPRING	S2-8	ROCK	55.7	LR	28.5	UPSal	8.8	GRIM	5.1	MC	1.5
Squaw_2011_RC153_FALL	S2-8	ROCK	57.5	MC	29.0	LR	8.2	GRIM	4.1	UCOL	0.8
Squaw_2009_1280_011_FALL	S2-8	ROCK	57.9	LR	18.4	UPSal	9.6	GRIM	6.6	MC	5.3
Squaw_2010_1281_050_SPRING	S2-8	ROCK	59.6	LR	32.7	UPSal	2.8	MC	1.9	GRIM	1.8
Omy_RockCr12-RC0316	S2-8	ROCK	62.2	MC	21.7	GRIM	6.7	LR	5.0	UPSal	3.5
Omy_RockCr12-RC0251	S2-8	ROCK	62.6	LR	21.7	GRIM	8.0	UCOL	6.7	MC	0.9
Omy_RockCr12-RC0308	S2-8	ROCK	63.5	LR	34.3	MC	0.8	GRIM	0.5	UPSal	0.4
Omy_RockCr12-RC0338	S2-8	ROCK	64.5	LR	31.5	UPSal	2.0	MC	0.9	GRIM	0.9
Squaw_2011_RC62_SPRING	S2-8	ROCK	64.9	GRIM	27.9	LR	5.8	MC	1.4	UPSal	0.1
Omy_RockCr12-RC0326	S2-8	ROCK	65.4	UPSal	20.1	MC	7.1	LR	3.4	UCOL	2.4
Squaw_2009_1280_007_FALL	S2-8	ROCK	67.5	LR	17.1	GRIM	12.0	UPSal	1.8	UCOL	0.7
Omy_RockCr12-RC0298	S2-8	ROCK	67.6	UCOL	26.4	MC	3.9	GRIM	1.2	LR	0.6
Squaw_2011_RC65_SPRING	S2-8	ROCK	68.5	UPSal	24.3	LR	3.4	GRIM	3.0	MC	0.5
Omy_RockCr12-RC0323	S2-8	ROCK	74.5	MC	11.4	GRIM	9.6	LR	3.1	UCOL	1.3
Squaw_2011_RC158_FALL	S2-8	ROCK	**77.3**	MC	7.4	UPSal	6.9	UCOL	5.5	GRIM	2.3
Omy_RockCr12-RC0252	S2-8	ROCK	**77.9**	UPSal	7.6	LR	7.2	MC	5.1	UCOL	1.2
Omy_RockCr12-RC0385	S2-8	ROCK	**78.9**	UPSal	13.2	LR	5.8	GRIM	1.5	MC	0.5
Omy_RockCr12-RC0383	S2-8	ROCK	**80.1**	GRIM	16.3	UPSal	1.7	LR	1.0	MC	0.5
Omy_RockCr12-RC0340	S2-8	ROCK	**81.2**	LR	14.5	MC	2.8	UCOL	0.9	GRIM	0.3
Squaw_2009_1280_019_FALL	S2-8	ROCK	**85.3**	LR	6.8	MC	6.2	UCOL	1.2	GRIM	0.4
Omy_RockCr12-RC0423	S2-8	ROCK	**85.5**	UCOL	8.9	LR	2.2	MC	1.8	GRIM	1.3
Omy_RockCr12-RC0256	S2-8	ROCK	**88.6**	LR	4.1	MC	2.9	UPSal	2.7	GRIM	1.5
Squaw_2010_1281_045_SPRING	S2-8	ROCK	**90.3**	LR	4.0	UCOL	2.0	UPSal	1.8	MC	1.7
Squaw_2010_1281_052_SPRING	S2-8	ROCK	**91.4**	UCOL	3.9	MC	3.5	GRIM	0.8	LR	0.3
Omy_RockCr12-RC0249	S2-8	ROCK	**91.6**	UCOL	7.0	LR	0.8	GRIM	0.3	MC	0.2
Squaw_2009_1280_015_FALL	S2-8	ROCK	**94.2**	LR	4.9	MC	0.8	UPSal	0.1	GRIM	0.0
Omy_RockCr12-RC0422	S2-8	ROCK	**94.3**	LR	3.8	GRIM	1.2	UPSal	0.5	MC	0.1
Squaw_2010_1281_046_SPRING	S2-8	ROCK	**98.0**	UPSal	0.8	LR	0.7	MC	0.3	MCSC	0.2
Omy_RockCr12-RC0327	S2-8	UCOL	38.4	ROCK	29.4	LR	20.2	GRIM	6.5	MC	3.6
Omy_RockCr12-RC0313	S2-8	UCOL	41.6	GRIM	30.0	LR	10.4	MC	6.4	UPSal	6.3
Squaw_2009_1280_016_FALL	S2-8	UCOL	49.8	ROCK	17.3	UPSal	15.7	LR	11.9	MC	4.7
Squaw_2009_1280_018_FALL	S2-8	UCOL	75.5	LR	10.6	MC	7.4	rock	5.9	UPSal	0.3
Omy_RockCr12-RC0416	S2-8	UPSal	42.8	ROCK	39.6	LR	8.4	UCOL	6.8	MC	1.6
Squaw_2011_RC66_SPRING	S2-8	UPSal	43.8	LR	36.4	rock	10.0	UCOL	4.5	GRIM	3.1

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Squaw_2011_RC64_SPRING	S2-8	UPSal	52.0	ROCK	39.9	UCOL	4.6	LR	2.6	GRIM	0.8
Squaw_2009_1280_013_FALL	S2-8	UPSal	52.3	ROCK	40.3	LR	3.6	GRIM	1.8	MC	1.6
Omy_RockCr12-RC0424	S2-8	UPSal	53.9	UCOL	23.3	rock	14.0	GRIM	6.3	LR	1.6
Omy_RockCr12-RC0314	S2-8	UPSal	55.1	UCOL	32.3	GRIM	6.1	rock	4.4	MC	1.2
Omy_RockCr12-RC0420	S2-8	UPSal	57.7	ROCK	24.5	UCOL	8.8	LR	6.3	GRIM	2.5
Omy_RockCr12-RC0329	S2-8	UPSal	67.8	ROCK	12.5	LR	7.9	GRIM	6.9	UCOL	4.6
Squaw_2011_RC154_FALL	S2-8	UPSal	85.0	LR	8.9	rock	2.6	UCOL	2.5	GRIM	0.9
Omy_RockCr12-RC0356	S2-8	UPSal	90.7	MC	3.9	rock	2.8	LR	2.6	GRIM	0.1
Squaw_2009_1280_55_FALL	S8-9	GRIM	34.0	ROCK	27.3	UCOL	24.4	UPSal	5.6	LR	4.9
Squaw_2011_RC61_SPRING	S8-9	GRIM	51.7	LR	20.6	rock	19.0	MC	7.2	UPSal	1.1
Squaw_2011_RC184_FALL	S8-9	GRIM	71.3	ROCK	13.1	MC	10.3	LR	3.4	UCOL	1.0
Squaw_2010_1281_058_SPRING	S8-9	LR	33.7	MC	31.7	GRIM	26.4	rock	5.0	UCOL	2.2
Squaw_2010_1281_056_SPRING	S8-9	LR	44.9	ROCK	29.5	UPSal	23.4	MC	1.1	GRIM	0.9
Squaw_2010_1281_057_SPRING	S8-9	LR	46.8	ROCK	33.2	GRIM	8.9	UPSal	8.4	UCOL	1.8
Squaw_2010_1281_053_SPRING	S8-9	LR	55.7	ROCK	24.4	MCSC	15.2	UPSal	3.5	GRIM	1.2
Squaw_2011_RC56_SPRING	S8-9	LR	55.7	ROCK	32.0	GRIM	5.4	UCOL	3.6	MC	1.9
Squaw_2011_RC183_FALL	S8-9	LR	63.5	GRIM	9.6	UPSal	9.0	UCOL	8.0	rock	6.1
Squaw_2010_1281_054_SPRING	S8-9	LR	64.0	ROCK	26.4	MCSC	9.2	GRIM	0.2	UPSal	0.2
Squaw_2010_1281_061_SPRING	S8-9	LR	79.2	ROCK	12.5	GRIM	5.2	UPSal	2.1	UCOL	0.9
Squaw_2011_RC164_FALL	S8-9	MC	41.0	ROCK	34.7	UCOL	21.8	UPSal	1.8	LR	0.6
Squaw_2011_RC180_FALL	S8-9	MC	46.7	ROCK	45.0	UPSal	8.0	UCOL	0.3	LR	0.0
Squaw_2010_1281_063_SPRING	S8-9	MC	56.4	LR	13.8	UPSal	13.6	rock	11.8	GRIM	2.6
Squaw_2011_RC51_SPRING	S8-9	MC	69.3	ROCK	10.3	LR	9.6	UCOL	9.1	GRIM	0.6
Squaw_2011_RC162_FALL	S8-9	MC	89.8	UPSal	3.5	rock	3.0	LR	2.4	UCOL	0.9
Squaw_2009_1280_54_FALL	S8-9	MC	90.1	UPSal	3.1	rock	2.3	LR	2.2	UCOL	1.7
Squaw_2009_1280_52_FALL	S8-9	MSSFS	53.4	GRIM	27.7	UCOL	10.6	LR	5.7	rock	2.1
Squaw_2011_RC175_FALL	S8-9	ROCK	30.6	UPSal	26.7	MC	25.4	LR	12.4	GRIM	2.5
Squaw_2009_1280_51_FALL	S8-9	ROCK	39.2	GRIM	36.9	LR	19.5	UCOL	1.9	MC	1.9
Squaw_2011_RC174_FALL	S8-9	ROCK	39.3	MC	27.1	LR	23.1	UCOL	9.5	GRIM	0.9
Squaw_2011_RC171_FALL	S8-9	ROCK	43.8	LR	28.5	MC	18.9	UPSal	7.8	GRIM	0.8
Squaw_2011_RC167_FALL	S8-9	ROCK	44.5	UPSal	31.9	GRIM	11.3	LR	9.2	UCOL	2.4
Squaw_2011_RC179_FALL	S8-9	ROCK	47.4	LR	14.7	MC	13.6	UPSal	13.2	UCOL	7.1
Squaw_2011_RC163_FALL	S8-9	ROCK	49.7	UPSal	33.4	LR	6.3	UCOL	5.5	GRIM	4.7
Squaw_2011_RC168_FALL	S8-9	ROCK	50.3	LR	18.8	MC	18.7	UCOL	10.7	UPSal	1.2
Squaw_2011_RC170_FALL	S8-9	ROCK	50.5	UPSal	27.2	UCOL	9.1	LR	6.5	GRIM	3.8
Squaw_2011_RC173_FALL	S8-9	ROCK	50.9	MC	36.9	UPSal	5.2	UCOL	4.9	LR	1.6

Sample ID	River reach	1st rank	Prob.	2nd rank	Prob.	3rd rank	Prob.	4th rank	Prob.	5th rank	Prob.
Squaw_2010_1281_062_SPRING	S8-9	ROCK	57.4	UCOL	23.6	LR	14.0	GRIM	3.1	UPSal	1.7
Squaw_2011_RC53_SPRING	S8-9	ROCK	64.5	LR	31.5	UPSal	2.0	MC	0.9	GRIM	0.9
Squaw_2009_1280_57_FALL	S8-9	ROCK	69.3	GRIM	9.8	UCOL	7.1	LR	6.2	UPSal	6.1
Squaw_2011_RC60_SPRING	S8-9	ROCK	**88.0**	MC	9.0	LR	1.7	UCOL	1.1	GRIM	0.1
Squaw_2011_RC59_SPRING	S8-9	ROCK	**89.6**	MC	7.5	LR	2.0	UPSal	0.6	GRIM	0.3
Squaw_2011_RC58_SPRING	S8-9	ROCK	**93.3**	LR	3.1	UPSal	1.1	MC	1.0	UCOL	0.5
Squaw_2010_1281_059_SPRING	S8-9	ROCK	**93.7**	MC	3.5	LR	1.8	UPSal	0.9	UCOL	0.1
Squaw_2011_RC52_SPRING	S8-9	UCOL	38.2	ROCK	24.6	LR	18.2	MC	9.5	UPSal	6.1
Squaw_2011_RC152_FALL	S8-9	UCOL	39.5	LR	23.3	GRIM	18.7	rock	11.6	MC	3.5
Squaw_2010_1281_055_SPRING	S8-9	UCOL	62.7	ROCK	24.6	UPSal	3.7	GRIM	3.4	MC	3.1
Squaw_2009_1280_56_FALL	S8-9	UCOL	89.9	ROCK	4.0	GRIM	2.7	LR	2.4	MC	0.7
Squaw_2011_RC57_SPRING	S8-9	UPSal	34.3	GRIM	30.9	rock	30.7	LR	3.5	MSSFS	0.3
Squaw_2009_1280_58_FALL	S8-9	UPSal	37.6	ROCK	27.7	LR	19.2	GRIM	13.4	UCOL	1.2
Squaw_2011_RC49_SPRING	S8-9	UPSal	41.2	ROCK	34.1	MC	21.9	LR	2.1	GRIM	0.4
Squaw_2011_RC172_FALL	S8-9	UPSal	42.0	LR	30.0	rock	15.1	MCSC	7.7	MSSFS	1.9
Squaw_2010_1281_060_SPRING	S8-9	UPSal	46.5	ROCK	26.2	LR	22.8	GRIM	3.1	UCOL	1.3
Squaw_2011_RC54_SPRING	S8-9	UPSal	70.6	UCOL	28.4	LR	0.4	GRIM	0.3	rock	0.2
Squaw_2011_RC55_SPRING	S8-9	UPSal	87.4	ROCK	9.4	LR	2.1	UCOL	0.7	MC	0.3
Squaw_2009_1280_53_FALL	S8-9	UPSal	88.8	UCOL	4.6	LR	4.1	rock	1.5	GRIM	0.8

Appendix E. References

71 FR 834. Federal Register. Vol. 71, No.3. January 5, 2006. Rules and Regulations

Allen, B., Munz, C., and Harvey, E. 2013. Fish Distribution and Population Dynamics in Rock Creek, Klickitat County, Washington. U.S. Geological Survey and Yakama Nation. Cook, WA.

Aspect Consulting LCC. 2008. Watershed Management Plan Rock-Glade Watershed (WRIA 31). Ecology Watershed Planning Grant No. G020010.

Bunte, Kristin and Steven R. Abt. 2001. Sampling Surface and Subsurface Particle-Size Distributions in Wadeable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring. Rocky Mountain Research Station RMRS-GTR-74, 428 pages.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007. Carcass counts. Pages 59-86 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Faulkner, J. R., S. G. Smith, W. D. Muir, D. M. Marsch, and J. G. Williams, 2010 Survival estimates for the passage of spring migration juvenile salmonids through Snake and Columbia River Dams and reservoirs, 2010. by NOAA Fisheries, for BPA project # 19930290.

Gallagher, S.P., P.K.J. Hahn, and D.H. Johnson. 2007. Redd counts. Pages 197-234 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Harrelson, C.C., Rawlings, C.L., Potyondy, J.P., (1994). Stream channel reference sites: An illustrated guide to field techniques. US Department of Agriculture Forest Service General Technical Report RM-245. Fort Collins, CO. USDA U.S. Forest Service.

Heil, N. (Ed) 2009. National Wild Fish Health Survey - Laboratory Procedures Manual. 5.0 Edition. U.S. Fish and Wildlife Service, Warm Springs, GA

Hauer Richard F. and Gary A. Lamberti. 1996. Methods in Stream Ecology. Academic Press. San Diego, CA.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory Area 31. Washington State Conservation Commission. Olympia, WA.

Matala, A. 2012. Evaluation of steelhead trout (*Oncorhynchus mykiss*) in Rock Creek watershed of the middle Columbia River Basin. Columbia River Inter-Tribal Fish Commission. Hagerman, ID.

Matala. A. 2013. Genetic evaluation of steelhead trout (*Oncorhynchus mykiss*) in the Rock Creek watershed of the middle Columbia River Basin. Columbia River Inter-Tribal Fish Commission. Hagerman, ID.

Montgomery, D.R., & Buffington, J.M. (1998). Channel processes, classification, and response, in Naiman, R. and Bilby, R., eds., River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. New York. Springer-Verlag.

Murphy, Brian R. and David W. Willis. 1996. Fisheries Techniques, Second Edition. American Fisheries Society.

Mobrand Biometrics, Inc. 2004. Ecosystem Diagnosis and Treatment Online User Manual.

Mobrand Biometrics, Inc. 2004. Ecosystem Diagnosis and Treatment Scenario Builder User Manual.

Northwest Power and Conservation Council. 2004. Data taken from the Lower Mid-Columbia Mainstem Subbasin Plan. NPCC, Portland, OR.

NOAA Fisheries. 2009. Rock Creek Recovery Plan for the Middle Columbia River Steelhead DPS.

Sloat, M.R and Osterback, A.K. 2013. Maximum stream temperature and the occurance, abundance, and behavior of steelhead trout (*Oncorhynchus mykiss*) in a southern California stream. Canada Journal Fish. Aquat.Sci 70:64-73 (2013)

WRIA 31 Planning Unit. 2008. Watershed Management Plan Rock-Glade Watershed (WRIA 31). Project No. 030009-004-01. January 2008.

Washington State Department of Ecology. 2010. Washington State Department of Ecology Stream Flow Monitoring. https://fortress.wa.gov/ecy/wrx/wrx/flows/station

Washington State Department of Ecology. 2012. Water Quality Standards for Surface Waters of the State of Washington. Chapter 173-201A WAC. Publication No. 06-1-091. January 2012.

Wolman, M.G., 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophyisical Union. 35(6):951-956.